CALIFORNIA CENTER FOR INNOVATIVE TRANSPORTATION
INSTITUTE OF TRANSPORTATION STUDIES
UNIVERSITY OF CALIFORNIA, BERKELEY

Limited Deployment Pilot Project: Monitoring Truck Traffic in Caltrans District 7

Ali Mortazavi, Ph.D. Senior R & D Engineer
Will Tabajonda, Graduate Student
Linda Fogel, Author
Seongkyun Cho, Graduate Student
John Drazin, Undergraduate Student
Ashkan Sharafsaleh, P.E. Senior R&D Engineer

CCIT Research Report
UCB-ITS-CWP-2011-1

ISSN 1557-2269

The California Center for Innovative Transportation works with researchers, practitioners, and industry to implement transportation research and innovation, including products and services that improve the efficiency, safety, and security of the transportation system.

CALIFORNIA CENTER FOR INNOVATIVE TRANSPORTATION
INSTITUTE OF TRANSPORTATION STUDIES
UNIVERSITY OF CALIFORNIA, BERKELEY

Limited Deployment Pilot Project: Monitoring Truck Traffic in Caltrans District 7

Ali Mortazavi, Ph.D. Senior R& D Engineer
Will Tabajonda, Graduate Student
Linda Fogel, Author
Seongkyun Cho, Graduate Student
John Drazin, Undergraduate Student
Ashkan Sharafsaleh, P.E. Senior R&D Engineer

CCIT Research Report
UCB-ITS-CWP-2011-1

This work was performed by the California Center for Innovative Transportation, a research group at the University of California, Berkeley, in cooperation with the State of California Business, Transportation, and Housing Agency's Department of Transportation, and the United States Department of Transportation's Federal Highway Administration.

The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the State of California. This report does not constitute a standard, specification, or regulation.

August, 2011

EXECUTIVE SUMMARY

Truck transportation affects every aspect of traffic and infrastructure. Because large trucks cause the majority of damage and stress to roadways and bridges as well as contribute significantly to congestion, it is important to have accurate, real-time data on the number of trucks on the roadways, peak travel times, lane use, and where trucks are going on the highway system. Currently, Caltrans relies on data collected from Automated Vehicle Classification (AVC) stations and manual census counts at specific locations to monitor and manage truck traffic. This technology is expensive, time-consuming, and disruptive to install as well as costly to maintain, therefore it has not been deployed widely.

A less-expensive and easier-to-install wireless technology was tested in a small-scale trial in 2006 with positive results. The CASE Global Technologies Traffic Monitoring System 100 (TMS 100, previously called the Infotek Wizard) performed with at least 95% accuracy compared to the existing AVC system. This collaborative study between CCIT and Caltrans evaluated whether the TMS wireless technology could provide reliable, real-time data on a broader basis. The evaluation focused on District 7, which encompasses the heavily-trafficked areas around the Los Angeles and Long Beach ports. Although TMS units were installed at 20 sites, only 3 were used in the study due to unforeseen circumstances that shortened the evaluation period.

The TMS solution uses a wireless modem with programmable software. It collects traffic information from the loop detectors and applies an algorithm to the data in real time. The processed results are relayed to traffic management centers via a cellular network. The software is compatible with several major database systems. The company also offers a solar-powered unit (TMS 300) that can be used in locations that do not have accessible A/C power.

The scope of the study involved installing the TMS 100 units, customizing the TMS algorithm, adjusting the calibration, devising a system to use on-site video taken simultaneously as ground-truth data to determine accuracy, and comparing the TMS data to the data of the existing AVC system.

To evaluate the TMS 100, the intent was to collect 60-minutes of TMS and AVC aggregated data over a period of two weeks and then compared those results. However, the available staffing and time were limited due to Caltrans budgetary constraints and then further reduced because of a major vehicle accident at one of the evaluation sites, so the team could only collect one to two days worth of aggregated data.

Although this study was limited in the number of sites evaluated, the results showed the TMS 100 performed with at least 95% accuracy, as noted in the 2006 pilot. Beyond the high level of accuracy demonstrated in the evaluation, the TMS solution offers many other benefits. The

TMS 100 requires little or no construction, is easy to install (one or two sites can be deployed in a day), can use the existing infrastructure, provides remote access for calibration, has lower per-unit costs, and is inexpensive to maintain. In addition, having a solar-powered option expands the areas that it can be installed. Because the system is less expensive and easier to install, more data collection points can be established to track traffic patterns, better plan ramp metering, manage congestion, and monitor pavement conditions for maintenance.

This report contains the following:

- Installation instructions
- Description of how to customize the TMS algorithm
- Setup and calibration information
- Evaluation methodology and results
- TMS User Manual

PROJECT FACT SHEET

Title:	Limited Deployment Pilot Project: Monitoring Truck Traffic in Caltrans District 7
Sponsor:	Caltrans Division of Research and Innovation
Executing Organization:	California Center for Innovative Transportation 2105 Bancroft Way, Berkeley, CA 94720 Phone: (510) 642-4522 Fax: (510) 642-0910
Execution Period:	1/15/2009 – 6/30/2010
Contract Amount:	$250,000
Principal Investigator:	Professor Samer Madanat
Center Director:	Thomas H. West, Executive Director, CCIT
Project Manager:	Ali Mortazavi, Senior R&D Engineer, CCIT
Administrative Officer:	Richard Kleinman, CCIT
Additional Researchers:	Will Tabajonda, Graduate Student Researcher, CCIT Seongkyun Cho, Graduate Student Researcher, CCIT John Drazin, Undergraduate Student Researcher, PATH Ashkan Sharafsaleh, Senior R&D Engineer, PATH

DISCLAIMER STATEMENT

This document is disseminated in the interest of information exchange. The contents of this report reflect the views of the authors who are responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the State of California or the Federal Highway Administration. This publication does not constitute a standard, specification or regulation. This report does not constitute an endorsement by the Department of any product described herein.

For individuals with sensory disabilities, this document is available in Braille, large print, audiocassette, or compact disk. To obtain a copy of this document in one of these alternate formats, please contact: the Division of Research and Innovation, MS-83, California Department of Transportation, P.O. Box 942873, Sacramento, CA 94273-0001.

ACKNOWLEDGEMENTS

The project team owes special thanks to Caltrans employees **Lianna Bergan** and **Jesse Gonzales**, who were injured while helping the project team collect data along CA-710.

The project team also warmly thanks the following people, in no particular order, who invaluably helped the project by committing their time and knowledge. Anyone mistakenly forgotten please accept our deepest apologies.

- **Frank Quon**, **Allen Z. Chen**, and **Steve M. Malkson**, Caltrans District 7
- **Homar Noroozi** and **John Slonaker**, Division of Research and Innovation, Caltrans
- **Mike Poursartip**, CASE Systems

This work was supported by Caltrans Division of Research and Innovation.

Limited Deployment Pilot Project: Monitoring Truck Traffic in Caltrans District 7

Final Report – July, 2010

Prepared by:

Ali Mortazavi, Ph.D. Senior R&D Engineer
Will Tabajonda, Graduate Student
Linda Fogel, Author
Seongkyun Cho, Graduate Student
John Drazin, Undergraduate Student
Ashkan Sharafsaleh, Senior R&D Engineer

For:
CALIFORNIA DEPARTMENT OF TRANSPORTATION

Table of Contents

Executive Summary iii

Project Fact Sheet v

Disclaimer Statement vi

Acknowledgements vii

California Department of transportation 1

Table of Contents 2

1 Introduction and Problem Statement 5

2 Background 8

3 Technical Approach 11

4 Equipment Installation Documentation 12

4.1 TMS Loop-Detection System 12

4.2 TMS 100 Algorithms 13

4.3 TMS 100 Installation Instructions 14

4.3.1 SIM Card Installation Instructions 14

4.3.2 Software Installation Instructions 15

4.3.3 Cable-Mapping Guide 16

4.3.4 Field Installation 17

4.3.5 Communications Check 18

4.4 TMS 100 System Setup and Calibration 19

4.4.1 Communicating with the TMS 100 19

4.4.2 Calibrating the Loop Detector 20

4.5 Solar TMS 300 Installation 23

5 Data Collection and Evaluation Plan 25
5.1 Site Selection 25
5.1.1 Physical Characteristics 25
5.1.2 Traffic Characteristics 27
5.1.3 Video Camera Placement 28
5.2 Data Collection 29
5.2.1 Video Data Collection and Processing 29
5.3 Long-Vehicle Classification Criteria 31
5.3.1 TMS 100 and AVC Data Collection and Processing 31
6 Results 34
6.1 Performance Measure Parameters for Video Comparison 34
6.2 AVC Validation Results 35
6.3 TMS Evaluation Results 38
6.3.1 TMS PVR Data Comparison Results 38
6.3.2 TMS Aggregated Data Comparison Results 40
7 Conclusions 56
8 References 58
Attachment 1. Accident Pictures 61
Attachment 2. Locations of Installed TMS 100 Units 64
Attachment 3. Schematic of Data Collection Set up 65
Attachment 4. TMS 100 Handbook 67

1 INTRODUCTION AND PROBLEM STATEMENT

A large number of trucks travel to and from Los Angeles area ports, contributing significantly to traffic congestion. Large trucks also cause the majority of damage and stress to roadway surfaces and bridges. Because truck transportation impacts every aspect of traffic and infrastructure in the Los Angeles area, it must be monitored and managed effectively.

To address this issue, it is important to have accurate, real-time census data on the number of trucks on the roadways, peak travel times, lane use, and where trucks travel on the highway system after leaving the port areas. Currently, Caltrans relies on data collected from Automated Vehicle Classification (AVC) stations and manual census counts at specific locations. The majority of the data collection and analysis is based on professional experience and has not been standardized or documented. In addition, collecting traffic data has been limited because of cost.

Caltrans's existing technology for automated and electronic traffic-count systems, such as AVC and Weigh In Motion (WIM), is not extensive enough to provide the data necessary to address the issues around truck traffic. Truck sensors and piezoelectric traffic counters have been installed at only a select number of sites because the equipment is too expensive for large-scale deployment. Because the sensors must be placed in the pavement, installation is time consuming and disruptive, requiring road closures that cause traffic delays and added congestion. Additionally, the complexity of the equipment requires substantial ongoing maintenance costs. Radar detection alternatives have also proven to be costly and resulted in inaccurate data.

The core objective of this project was to evaluate whether the InfoTek Wizard system,[1] a less-expensive and easier-to-install wireless technology, could provide the same or better information on truck traffic. The system collects data from existing loop detectors. The post-processed results are relayed to traffic management centers via a GSM wireless network or optional Ethernet or fiber network. The device uses the Traffic Monitoring System Algorithm to classify vehicles. If the new technology proves accurate, it offers the following benefits:

- No construction costs
- Ability to deploy one to two sites per day
- Lower per-unit costs
- More data collection points
- Option to use the existing infrastructure, including installed single loops and cabinets

[1] After the project began, InfoTek was acquired by CASE Global Technologies (CGT), which changed the name of the software and equipment to Traffic Monitoring System (TMS). This report uses the current name of TMS.

- Remote access
- Low-cost maintenance

By expanding the network of truck-counting sensors, the data collected will:

- Allow increased tracking of truck-traffic patterns, including seasonal and holiday traffic
- Inform better planning of ramp metering and congestion management
- Provide detailed statistics on goods movement in the monitored area
- Give information on pavement use for highway maintenance planning

The efficacy of using the TMS 100 (InfoTek Wizard) solution was confirmed in a small-scale 2006 demonstration project as part of the Innovative Corridors Initiative public-private partnership program. The pilot project, which tested three sites each in Districts 4 and 7, showed promising results: The less-costly TMS 100 solution performed with at least 95% accuracy compared to the AVC system. The next step prior to full commercial deployment was to test and evaluate the TMS units on a larger scale along two of the most heavily traveled truck corridors in the Los Angeles area.

The initial proposal for this project was to deploy the TMS equipment and software at 26 single-loop sites to track where trucks are going after leaving the ports of Los Angeles and Long Beach. District 7 proposed 10 locations on Interstate 710, leading to and from the ports of Los Angeles and Long Beach, and 16 sites on State Route 60, which carries a significant amount of truck traffic into and out of the Los Angeles basin.

To evaluate the TMS 100, CCIT used video data as well as data from the existing AVC systems along I-710 and CA-60 as a comparison. To use the AVC data as a ground-truth baseline, CCIT needed to first confirm that the AVC detectors were valid and accurate. To assess both the AVC and TMS 100 data, the deployment sites were videotaped to provide a one-to-one comparison. This document describes the methodology and procedures involved in validating the AVC system and evaluating the TMS 100 data using both the AVC and video data. The report also documents how to install and set up the TMS equipment and software.

Although the intent was to evaluate 26 sites, because of unexpected circumstances and funding and time constraints, the project could test only three sites for a limited period of time. One problem was that the initial AVC data collected for the purpose of comparison was not usable because the sensors were not correctly calibrated. Caltrans personnel needed to perform the calibration. However, because of work furloughs and a shortage in staffing, there was not enough time to complete all the tasks for the original number of stations. The collection time also needed to be shortened. Then part way through the project, the CCIT researchers and Caltrans staff were involved in a multicar collision while collecting video data at one of the

stations. The team sustained both minor and major injuries, causing the available staffing and resources at the coordinating Caltrans office to be further reduced. As a result, the CCIT team could only obtain video data for one station. The long-term evaluation comparing the TMS system to the ground-truth AVC data continued but that happened at a decelerated pace and with several modifications.

Despite these obstacles, the project was able to confirm the positive results of the initial pilot and demonstrate the performance accuracy of the TMS 100. The project also had the opportunity to install the TMS 300, which uses solar power, because two of the sites selected did not have adequate power. The TMS 300 offers an alternative for locations that do not have accessible A/C power, as well as for new loop detector stations and road construction sites that require fast installations.

2 BACKGROUND

The detection and classification of vehicles are critical for the efficient operation of streets and highways (Harlow, 2001), including signal and traffic control (Rrouphail, 1995; Klein, 2001; Dillenburg, 1995), ramp metering (Kunigahalli, 1995; Kell, 1990), incident referencing and mapping (Ritchie, 1995; Klein, 2001; Darter, 2007), driver information system (Nojima, 1995), and road management and design.

Vehicle classification is especially critical for tracking trucks, because truck traffic plays a significant role in many aspects of transportation planning, highway operational analysis, and pavement and bridge design (Saito, 2009). Thus, it is important to select appropriate detectors to gather relevant truck traffic data.

Methods for collecting truck traffic data can be divided into three categories: automated or electronic traffic-count systems, such as WIM, inductive loops, pneumatic detectors, and AVC; video surveillance; and visual classification counts, such as tally sheets and mechanical counting boards (Saito, 2009). This assessment focuses on automated and electronic systems, because most truck-tracking systems used by Caltrans are automated. In addition, video surveillance costs too much, and visual manual counting requires a highly skilled labor force.

An inductance loop system is one of the traditional methods for automated vehicle classification (U.S. Department of Transportation, 1997). It has some advantages. It is fairly immune to weather conditions (Juba, 1996). Because a dual loop system has relatively higher accuracy—up to 96.2%, depending on the algorithm (Pursula, 1994)—it is used to acquire ground-truth data to evaluate the performance of other vehicle classifiers, such as video image processors (Minnesota Department of Transportation, 2002; Middleton, 2000), infrared detectors (Minnesota, 2002; Middleton, 2000; Minnesota, 1997), and microwave radar (Minnesota, 1997; Middleton, 2000; Saito, 1995). It can provide basic traffic data, such as volume, presence, occupancy, speed, headway, and gap, and it has a lower lifecycle cost compared to some nonintrusive detectors. Assuming a lifecycle of 15 years, the average annual cost for one unit of a typical loop system, including installation and maintenance, is $1,510 (Martin, 2003).

However, a loop system also has also some limitations. It causes disruptions during installation (Martin, 2003; Victoria, 2004), is inconvenient to repair (Carlson, 1997; Victoria, 2004), and is prone to pavement failures (Carlson, 1997; Victoria, 2004), damage caused by snow removal equipment (Luz, 2000; Victoria, 2004), and miscalculating axles as separate vehicles (Carlson, 1997).

Pneumatic road tube detectors are the oldest and most widely used method for counting axles to classify vehicles (U.S. Department of Transportation, 1997; Skszek, 2001) because of their simplicity, lower cost (Elena, 2000), and ease to install. However, these detectors cannot count occupancy or presence, and they can be severely influenced or damaged by heavy snow, snow removal equipment, rain, and extreme temperatures. They sometimes also miss low-speed vehicles (Martin, 2003) and vary greatly in accuracy according to the circumstances.

Piezoelectric sensors, bending plates, load cells, and capacitance mats are traditional WIMs. They vary in accuracy, with load cells being the most accurate (1% of standard deviation in the confidence interval), followed by bending plates (2%) and piezoelectric sensors (10%) (Martin, 2003). But based on the lifecycle cost, the order is reversed: piezoelectric sensors are the least costly at $4,424 per lane for a 12-year life, followed by bending plates at $4,990, and load cells at $7,296. Fiber optics is becoming recognized as an alternative for replacing traditional WIM methods because of its lower cost, higher accuracy, absence of electromagnetic interference, and ease of installment (Safaai-Jazi, 1990; Martin, 2003).

Usually, AVC combines several detectors, such as two loop detectors with a piezo sensor between the loops or two piezo sensors with a loop detector in between. A loop-piezo-loop (LPL) combination is commonly recommended. According to a 48-hour test done by Harvey (1995), there was not a significant difference in accuracy between an LPL combination (76.6%) and a PLP system (75.3%), but piezo sensors cost more. While a traditional dual-loop system costs $1,510 annually (Martin, 2003), a PLP costs $4,424 (Taylor, 1993). Considering the time span between 2003 and 1993 when these estimations were gathered, the cost gap between dual loop and PLP could even be larger.

A potential cost-effective method is the use of wireless modems and programmable software to collect data and transmit it directly to a database. The TMS 100 was developed in 2005 to provide a less expensive solution to detect long vehicles using single-loop sensors. The efficacy of using this single-loop detector technology was confirmed in a small-scale 2006 demonstration project as part of the Innovative Corridors Initiative. To evaluate the accuracy of the TMS 100, three existing Caltrans AVC sites in two districts were selected to use as a comparison. Both systems collected data for one week on the number of vehicles longer than 40 feet. The results were very promising, with the less costly TMS 100 performing with at least 95% accuracy when compared to the AVC stations.

The system evaluated consisted of TMS 100 intelligent GPRS/EDGE wireless modems and integrated, programmable software that was able to post-process the collected data to provide traffic information. The system has 32 digital inputs and 8 digital outputs and can support up to 28 loops (14 loops in a dual-loop configuration). It collects traffic data from loop detectors and applies algorithms to the collected data in real time. The device summarizes volume,

occupancy, and long-vehicle counts into typical 15-minute bins. The post-processed results are relayed to traffic-management centers via a cellular network. TMS 100 works with existing polling systems and the data collecting software is compatible with Oracle, MS Access, and MS SQL databases. TMS 100 is used in Caltrans District 10 as a controller in traffic-monitoring stations (Darter, 2007).

Usually, a single loop assumes the vehicle length when it measures speed or classifies vehicles. This method of assumption can cause incorrect classifications (Lin, 2004). However, the Caltrans TMS 100 experiment showed that vehicles with lengths over 40 feet are detected correctly. Considering that most trucks are over 40 feet, the TMS 100 can provide adequate truck traffic data using the current single-loop infrastructure instead of the more expensive AVC or WIM systems. This research evaluates whether the TMS 100 can produce accurate truck-traffic data and provide a long-term, cost-effective solution.

3 TECHNICAL APPROACH

To assess the accuracy of the TMS 100 on a larger scale, the team selected evaluation sites based on physical characteristics, traffic volume, and the availability of AVC stations. The original goal was to compare a minimum of a week's worth of TMS data to the AVC data. However, before testing the TMS 100, the data collected by the AVC systems needed to be validated to establish a baseline.

To validate the AVC data, the team videotaped the traffic for a 30-minute period to use as a one-to-one comparison. The 30-minute videotape data was used to verify the robustness of the AVC data. This process involved installing video cameras at each evaluation site and then manually matching the recorded traffic to the AVC data. Another separate video recording was also used to evaluate the TMS data by manually matching the recorded traffic to the TMS data. Using the video recordings, both the AVC and TMS systems were further calibrated and fine-tuned as necessary.

In addition to the TMS 100, the evaluation used the solar-powered TMS 300 at one of the sites that did not have adequate power. The TMS 300 has similar features to the TMS 100, but offers the advantage of using sustainable energy.

The project also documented the TMS installation and set-up procedures.

4 EQUIPMENT INSTALLATION DOCUMENTATION

4.1 TMS LOOP-DETECTION SYSTEM

TMS is a loop-detection application that delivers volume, speed, loop occupancy, and length classification data over either a secure wireless GSM network or existing fiber (see Figure 1). The TMS solution can use the existing inductive loop infrastructure, and it does not interfere with equipment such as traffic controllers and ramp meters. Traffic data is remotely and automatically collected into an Oracle, Microsoft SQL Server, or Microsoft Access database; manual downloading is not required. The system can store traffic data for one month, even if the communication link is broken.

The application is pure Java software and runs on Java-programmable wireless modems installed in the traffic cabinets.

CASE Global Technologies offers three versions of the TMS solution. The TMS 100 was used for the majority of the evaluation. The TMS 200 was used briefly to perform the final communication check after the installation. The TMS 200 includes an additional serial port and an Ethernet port, which allowed the technicians to easily attach a laptop. It also has GPS for recording an accurate timestamp and location. The TMS 300 runs on solar power, so it can be used in areas where power is inconsistent or not available. The TMS 300 was used at one of the evaluation sites. On average, the TMS 100 requires less than 1 watt of power.

Beyond energy savings, TMS 300 is also a good alternative for new loop-detector stations and road construction sites that require fast installations. Like the TMS 100, it provides real-time data using cellular wireless communication. It can also be reset remotely.

TMS can be integrated with existing controllers and loop detectors. The TMS cable is connected directly to the loop detectors, and the GSM antenna mounts on top of the traffic cabinet for wireless connectivity. The system can withstand temperatures ranging from -13° F to + 162° F (-25° C to +72° C) and relative humidity from 5% to 95%.

TMS collects data via a wireless modem with sends it to a database located on a remote server. The data can then be post-processed at the remote site. For single-loop configurations, TMS summarizes volume, occupancy, and long-vehicle counts into 15-minute bins. The system can be calibrated remotely and customized to send real-time alert notifications, such as changing traffic conditions or predefined thresholds.

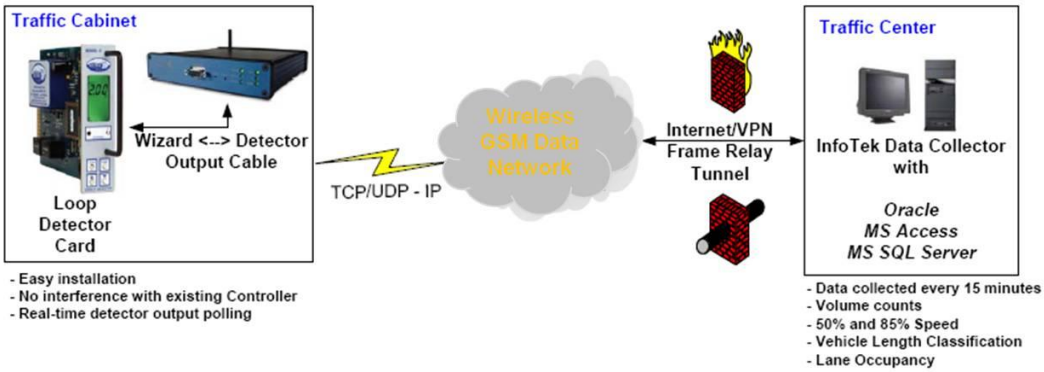


Figure 1: TMS system architecture (formerly called InfoTek)

4.2 TMS 100 ALGORITHM

The TMS algorithm, which is used to provide long-vehicle counts via each lane's inductive loop detector, is proprietary to CASE Global Technologies. Users can configure the algorithm parameters based on the characteristics of the site. After the system is set up, the long vehicle counts are uploaded to a centralized database.

The inductive loop-detector card reports the presence of each vehicle passing over the loop. The presence signal remains on while the vehicle passes over the loop.

The algorithm calculates the speed based on the selected reference lane and estimated average length. Typically, the reference lane is the left (fast) lane, which has mostly car traffic, so the average length is easier to estimate. The reference lane is then used to estimate the speed of traffic in the slower lanes based on the provided scaling factors. For example, the traffic in the right lane (where the longer vehicles typically travel) might travel at 90% of the speed in the fast lane. All other lanes, except for the HOV lane, base their speed on the reference lane and the scaling factors.

After the speed is estimated, the vehicle length is calculated based on the duration of the loop presence signal. Each vehicle is binned into one of two length classifications: long vehicles and all other vehicles. The user can adjust the length threshold. Through experimentation during this project, it was determined that a 50-foot threshold minimized misclassifications—all vehicles calculated over 50 feet are classified as long vehicles. Long vehicles typically are 60–65 feet, and the vast majority of other vehicles are significantly under 50 feet, so the 50-foot threshold provided a good enough gap.

The algorithm uses a collection interval to calculate the estimated speed. The estimated speed is recalculated for each lane based on the supplied time interval. The collection interval selected for this project was 1 minute. For example, if the speed in lane 3 is calculated at 58 MPH between 11:00 and 11:01, 58 MPH is then used as the speed estimate for the length

calculations from 11:01 to 11:02, when the next speed estimate is calculated. Longer or shorter time intervals can be used, but there are tradeoffs to consider. A 30-second interval provides a smaller sample set to estimate the speed, but is more responsive to changes in traffic speed. A 2-minute interval offers a larger sample set, but is less responsive to speed changes.

It was noted that long-vehicle count results are best when there is a steady flow of traffic. Count measurements during heavy traffic over the inductive loop can be accurate, but long-vehicle count calculations degrade as the traffic stops.

4.3 TMS 100 INSTALLATION INSTRUCTIONS

Setting up the TMS 100 includes installing the SIM card and software and creating a cable-mapping guide to attach the wires. These tasks can be performed off site. The tasks involved at the site include installing the physical unit and then performing a communications check to verify the data link. It is recommended that the TMS 100 be connected to the GSM network prior to field installation.

For more information about setting up and using the TMS 100, see the *TMS 100 User Guide* in 2.

4.3.1 SIM CARD INSTALLATION INSTRUCTIONS

1. Remove the front and rear screws.
2. Slide back the top cover.
   Caution: Do not touch the exposed processor.
3. Slide down the SIM card holder.
4. Make sure that the jumpers are set properly.
5. Break the SIM chip from the plastic card.
   Caution: Do not touch the metal contact of the SIM card.
6. Insert the SIM card and lock it into the holder.
7. Reassemble the unit.
8. Tag the TMS 100 with the APN address, telephone, IP address, and location.
9. Power on the TMS 100.

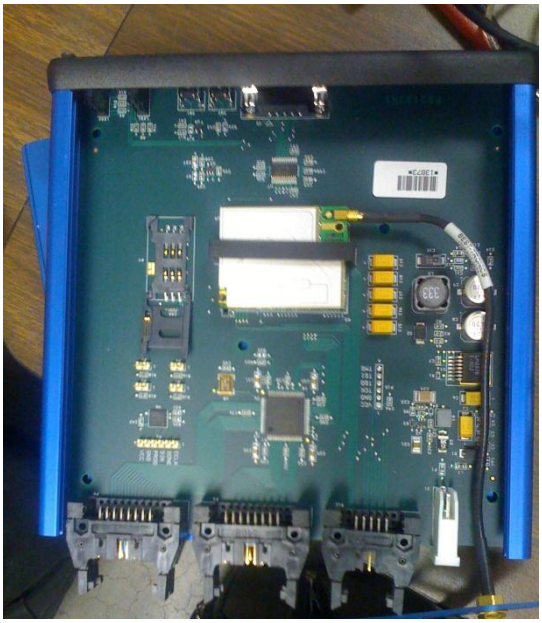


Figure 2. Inside view of a TMS 100 Unit

4.3.2 SOFTWARE INSTALLATION INSTRUCTIONS

1. Connect the computer to the TMS 100 with the serial cable.
2. Use a pin to select MODE 1 on the TMS 100.
3. Run the Nokia Configurator software on the computer.
4. Browse to select the software.
5. Click **>** to upload the software.
6. Select **Main** and click **Select**.
7. Set up the indicator lights as follows:
   a. Click **M2M System**.
   b. Click **System Parameters**.
   c. Select **GPRS always ON**.
   d. Select **Connection 1**.
   e. Select **TCP GPRS**.
   f. Enter the GPRS access point.
   g. Enter the APN name (for example, ct7mobile2.dot.ca.gov).
   h. For the gateway port, enter 12345.
   i. Click **Read Parameters**.
   j. Close the window.
   k. Exit and save the parameter settings.
8. Disconnect the serial cables and power cables.
9. Connect the power cable again. The system registration might take a few moments.
10. Access the box through the HyperTerminal.

4.3.3 CABLE-MAPPING GUIDE

Before installing the device in the cabinet, a cable-mapping guide is needed to show how each TMS 100 wire connection maps to a detector loop (see Figure 3). Creating the cable-mapping guide prior to installation would help streamline the installation process.

Station: *XX*, *XX* *Direction*	
TMS 100 Cables	**Lanes**
Channels 1–8	
Brown	Lane 1 E/B
White	Lane 2 E/B
Violet	Lane 3 E/B
Blue	Lane 4 E/B
Green	Lane 5 W/B
Yellow	Lane 6 W/B
Orange	Lane 7 W/B
Red	Lane 8 W/B

Figure 3. Sample cable-mapping guide

The cable-mapping guide corresponds to the lane nomenclature at the specific site. Within Caltrans District 7, the Traffic Management group and the Census group use different lane-naming schemes. The Census group designates the northbound and eastbound directions as main roads and numbers them 1–4. The Traffic Management group uses the lane closest to the cabinet as the main road, and it numbers the lanes 1–4 (see Figure 4).

When using shared cabinets, the Census group follows the Traffic Management nomenclature.

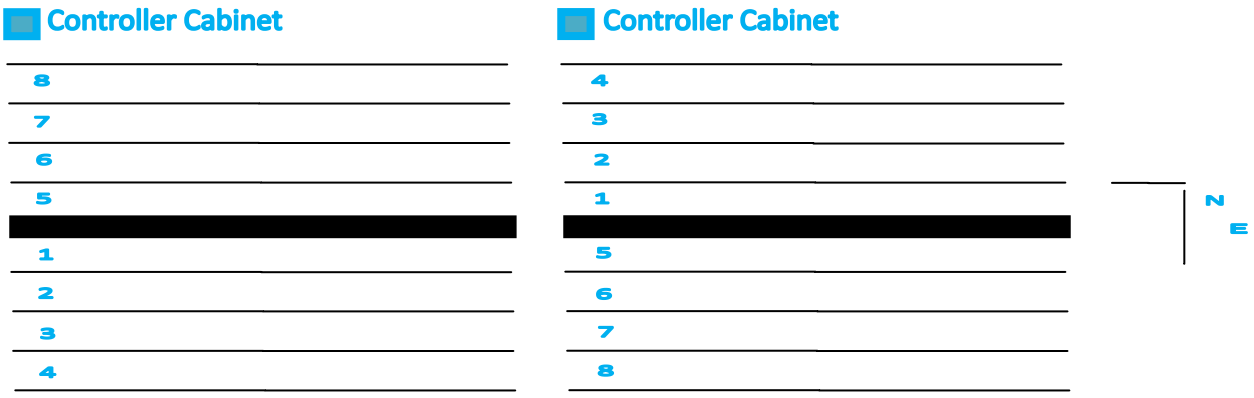


Figure 4. Lane naming schemes. Left: Census group uses the eastbound direction. Right: Traffic Management group uses the lane closest to the cabinet.

4.3.4 FIELD INSTALLATION

The physical TMS 100 unit connects to the Input File of the cabinet and plugs into a 120v power source. The TMS 100 has an 8-wire cable (Figure 5). Match the cable-mapping guide to the detector layout sheet to identify where on the controller landing board each cable wire goes. After the cable is landed properly, connect it to the corresponding digital input channel on the TMS 100 unit. Each cable must be grounded, and any unused wires must be wrapped with electrical tape (Figure 6).

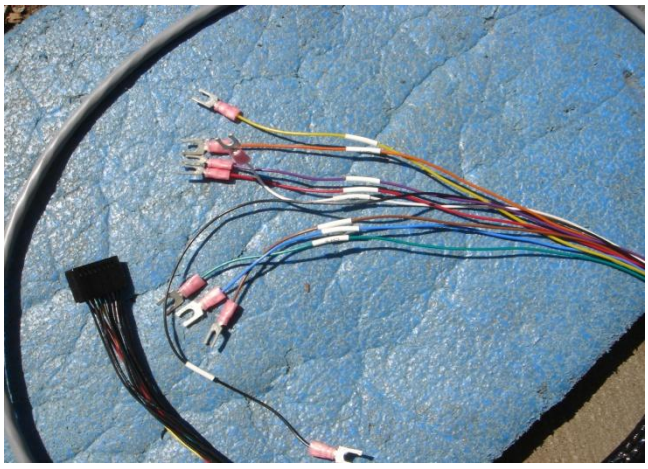


Figure 5. TMS 100 8-wire cable. Each wire corresponds to a single loop. Map the color-coded wires to the lanes beforehand, similar to Figure 3.

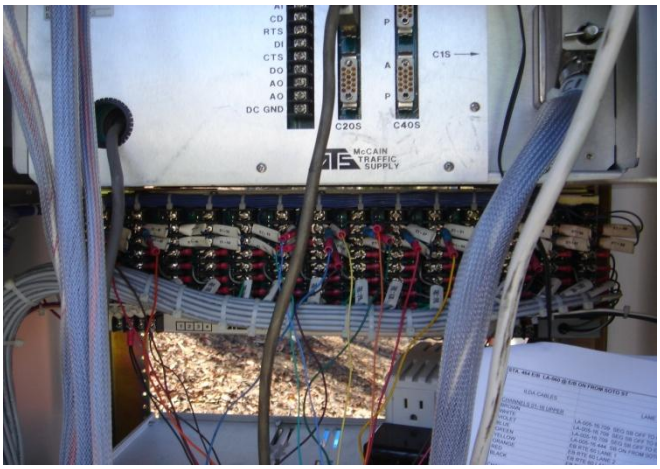


Figure 6. Land the individual input wires to the Input File according to the detector layout sheet and cable-mapping plan.

To install the antenna, drill a hole through the top of the cabinet. Thread the antenna bolt through the hole and connect the antenna wire to the TMS 100 (Figure 7). The last step is to connect the TMS 100 cable to the back of the unit (Figure 8).

Figure 7. Bolt the antenna through the top of the cabinet. Drill a larger hole through the paneling inside the cabinet to provide access.

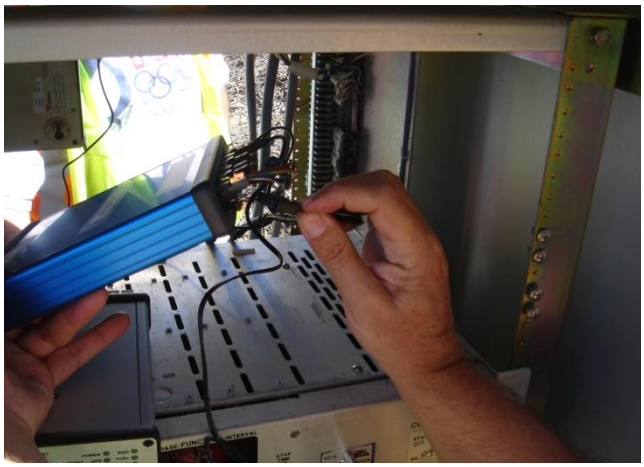


Figure 8. Connect the TMS 100 cable to the back of the TMS unit in the corresponding digital input port.

4.3.5 COMMUNICATIONS CHECK

After the installation was complete, the system needed to be checked to make sure that the cables were landed correctly and that the signal strength of the wireless connection could transfer data reliably.

At the time of installation, field technicians could not bypass the Caltrans network firewall using an external laptop modem to access the device's system. As a workaround, it was decided to attach a laptop directly to the unit. However, the TMS 100 does not provide a COM port. Instead, the TMS 200 unit, which includes a COM port, was used as a proxy to view live data and verify that the installation was correct.

Using the HyperTerminal interface, vehicle traffic was visually observed as it passed over the detector loops. The data was then compared to the live data from the TMS 200. After the ground verification was complete, the team checked that the main database was receiving the information by accessing the TMS 200 from the main terminal and verifying the connection.

Figure 9. Communications check using a laptop and TMS 200

4.4 TMS 100 SYSTEM SETUP AND CALIBRATION

To obtain high-quality data from the TMS system, each unit must be set up and calibrated to reflect the conditions specific to the site. Software setup and calibration can be performed remotely using the TMS 100's cellular wireless capability. However, loop-detector calibration must be performed on site to ensure that vehicles are correctly classified. The TMS system and loop-detector system (in-lane loop detectors and loop-detector cards) work in conjunction with each other, so they must be calibrated simultaneously and iteratively.

The main site-specific inputs are the number of lanes, average vehicle length, reference lane, and lane factor.

- Average vehicle length—Interior lanes with a higher volume of small vehicles will have a smaller average length compared to the outer lanes, which might carry higher volumes of large vehicles.
- Reference lane—Lane in which speeds will be referenced from. Ideally, the reference lane has consistent speeds (the leftmost lane has the most consistent speeds in most cases).
- Lane scaling factor—Percent decrease in speed moving away from the reference lane.

4.4.1 COMMUNICATING WITH THE TMS 100

You can access the TMS 100 through the HyperTerminal interface or a web browser.

4.4.1.1 HYPERTERMINAL INTERFACE

To use the HyperTerminal interface:

1. Select **Start > All Programs > Accessories > Communications > HyperTerminal**.
2. To connect the computer via the wireless GSM modem, from the drop-down menu, select **TCP**.
3. Enter the IP address of the TMS 100 unit.
4. If the network has a firewall, the firewall port might need to be changed. The port must be changed in the HyperTerminal TMS 100 unit.

If HyperTerminal is not installed:

1. In the Control Panel, select **Add or Remove Programs**.
2. Click **Add/Remove Windows Components**.
3. Click **Accessories and Utilities**, and then click **Details**.
4. Click **Communications**, and then click **Details**.
5. Select **HyperTerminal**, and then click **OK**.

4.4.1.2 WEB BROWSER

To access the TMS 100 system from a web browser, enter the IP address of the particular TMS unit in the address bar. The address is “http://<IP address of the modem>”.

4.4.2 CALIBRATING THE LOOP DETECTOR

The TMS 100 unit relies on the input from the loop detector system. The loop detectors must be calibrated to obtain quality data. As a baseline, set the loop detector sensitivity to mid-level settings. Detector cards vary from cabinet to cabinet, and some cards might need adjustment.

For this limited deployment project, Caltrans replaced the existing cabinet loop-detector cards to reduce the possibility of errors. It is recommended that technicians bring several new cards during installation in case problems arise or cards are broken.

Figure 10: Example of a detector card. Sensitivity varies between card manufacturers, so consult the user manual of each card type during calibration.

Next, the accuracy of the system needs to be assessed by observing oncoming large vehicles with known lengths and comparing the observations with the per vehicle records (PVRs) from the TMS 100 unit via the HyperTerminal. When a vehicle with a known length is seen downstream of the sensor, check the PVR as the vehicle passes by. If the vehicle length is consistent by type or class of vehicle, no further calibration is required. The process can be simplified by checking one lane at a time.

Two things to watch for are missing vehicles and cross-talk, an incident in which a vehicle triggers a count in the adjacent lane.

Missing vehicles can occur if the loop detector is too deep in the asphalt, so that it might not detect a passing vehicle. In this situation, increase the loop detector's sensitivity. However, increasing the sensitivity might also increase the average detected vehicle length because the effective size of the detector might increase.

Cross-talk can occur if the loop detector is too shallow in the asphalt or its sensitivity is set too high. In this situation, the sensitivity must be lowered. However, lowering the sensitivity might also decrease the average detected vehicle length because the effective size of the detector might decrease.

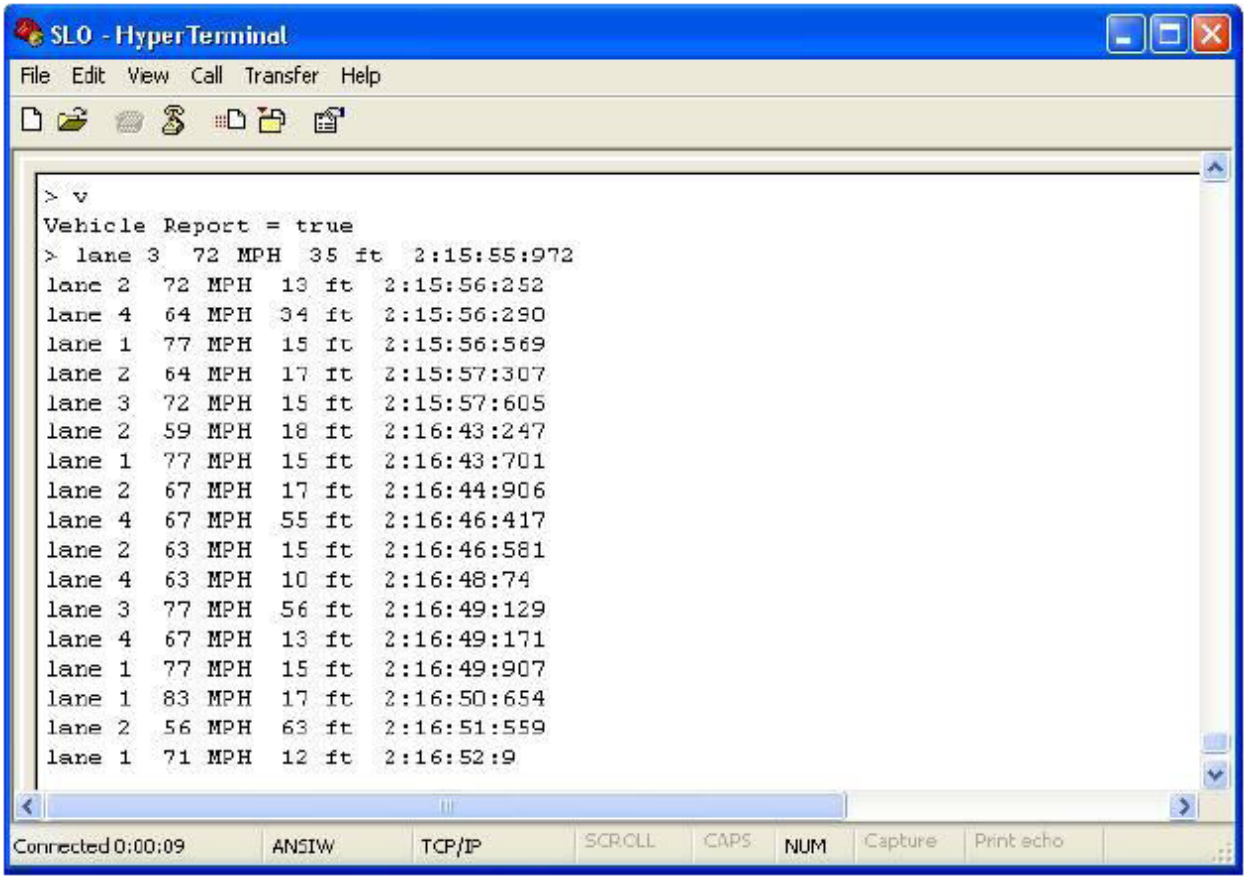

SLO - HyperTerminal
File Edit View Call Transfer Help
> v
Vehicle Report = true
> lane 3 72 MPH 35 ft 2:15:55:972
lane 2 72 MPH 13 ft 2:15:56:252
lane 4 64 MPH 34 ft 2:15:56:290
lane 1 77 MPH 15 ft 2:15:56:569
lane 2 64 MPH 17 ft 2:15:57:307
lane 3 72 MPH 15 ft 2:15:57:605
lane 2 59 MPH 18 ft 2:16:43:247
lane 1 77 MPH 15 ft 2:16:43:701
lane 2 67 MPH 17 ft 2:16:44:906
lane 4 67 MPH 55 ft 2:16:46:417
lane 2 63 MPH 15 ft 2:16:46:581
lane 4 63 MPH 10 ft 2:16:48:74
lane 3 77 MPH 56 ft 2:16:49:129
lane 4 67 MPH 13 ft 2:16:49:171
lane 1 77 MPH 15 ft 2:16:49:907
lane 1 83 MPH 17 ft 2:16:50:654
lane 2 56 MPH 63 ft 2:16:51:559
lane 1 71 MPH 12 ft 2:16:52:9
Connected 0:00:09
ANSIW
TCP/IP
SCROLL
CAPS
NUM
Capture
Print echo

Figure 11: PVR data via the HyperTerminal interface

If vehicle speeds or lengths are inconsistent, or it is observed that the loop detectors are missing vehicles or experiencing cross-talk, calibration is required. To refine the accuracy of the system, adjust the sensitivity of the detector card and the TMS software parameters until the PVR data approximates the live traffic.

Knowledge of the site hardware and typical traffic conditions can help with calibrating the system and deciding which inputs to change. Because the speed and vehicle length calculations come from two independent systems, the technician must decide whether to adjust the sensitivity of the loop-detector card or the TMS software parameter. For example, while the innermost lane might be considered the fast lane with little to no truck traffic in most situations, there are instances where the left lane might serve as an off-ramp for trucks, so the average vehicle length must be adjusted to reflect the truck traffic.

During calibration, the system needs about a one-minute settling period to accept the adjustments and gather new data.

4.5 SOLAR TMS 300 INSTALLATION

Station 041, one of the two sites experiencing power issues, was determined to be a good candidate to evaluate the solar-powered TMS 300.

Prior to installation, the location of the solar panel must be coordinated with Caltrans. For the solar panel to charge, it cannot be obstructed by trees or buildings. The solar panel is set at 196 degrees facing southwest at a 45-degree tilt based on the location's latitude. Another consideration is the location of the loops and the pull-box to determine the length of the conduit to connect the loops to the TMS 300 and terminate the loops at the NEMA enclosure.

After the location is selected, Dig-Alert, also known as Underground Service Alert (USA), must be informed so that they can inspect the area for underground utilities and other existing infrastructure. The USA permit takes about three days.

Either hand- or machine-digging can be used, depending on the regulations and agencies involved, such as Caltrans or the state environmental agency. Hand-digging has easier permit requirements.

The approximate field installation times, according to CASE Global Technologies, are:

- Drilling enclosures: 45 minutes
- Drilling and welding, fitting to foundation, and drilling poles: 45 minutes
- Assembling solar panel (includes bracket assembly, pole cap, conduit and cable attachment): 30 minutes
- Installing foundation and conduit: 2 hours
- Installing pull box: 45 minutes
- Pulling loops through the base pole (includes installing the pole to base and grounding rod): 1 hour
- Installing boxes on pole and soldering the DLC wire: 1 hour
- Installing pedestrian pad: 1 hour

When using rapid-set concrete, installing a TMS 300 box can be completed in three to four hours.

Figure 12. Left: Cabinet interior of a solar TMS 300. Right: Field installation.

5 DATA COLLECTION AND EVALUATION PLAN

Three sites were selected to evaluate the accuracy of the TMS 100 in classifying vehicles. CCIT's plan was to conduct the evaluation in two phases occurring simultaneously. The first phase focused on performing a one-to-one comparison of the TMS per vehicle records (PVRs) to 30-minutes of traffic captured via video. The goal for the second phase was to compare 60-minute bins of TMS aggregated data to AVC aggregated data over a period of two weeks. The AVC data was used as a ground-truth baseline.

However, the evaluation did not go as planned. In the process of comparing the TMS PVR data to the video data, it was discovered that some of the single-loop detector sensors as well as the TMS units were not calibrated, rendering the aggregated data that was already collected as useless. After the TMS 100 units were recalibrated, which took away time from the evaluation, the aggregated TMS and AVC data had to be recollected. The sensors were not recalibrated.

The combination of needing to redo the second phase and losing staffing because of the accident that occurred resulted in not being able to fulfill the second phase (see 1 for pictures of the accident). Instead of two weeks of aggregated data, the team could only collect aggregated data for one to two days for each evaluation site. However, one month (four weeks) of data was collected later in March 2011 which was analyzed in the fourth phase.

The following sections describe the evaluation tasks.

5.1 SITE SELECTION

The original pilot program called for 26 TMS 100 installation locations, with several locations having AVC stations. Of these 26 sites, 3 were selected because of their physical characteristics, traffic characteristics, and AVC availability:

- Station 098, eastbound along Route 60 (Figure 13)
- Station 037, northbound along Interstate 710 (Figure 14)
- Station 040, southbound along Interstate 710 (Figure 15)

5.1.1 PHYSICAL CHARACTERISTICS

The sites were chosen based on whether they had working sensors, provided good data, offered large shoulders for safety, and had good visibility. Google Earth and the Street View feature were also used to observe the physical site.

Figure 13. Route 60 eastbound, Station 098

Figure 14. Interstate 710 northbound, Station 037

Figure 15. Interstate 710 southbound, Station 040

5.1.2 TRAFFIC CHARACTERISTICS

Previous studies have shown that the performance of vehicle classification technology employing single-loop detectors changes with traffic flow, especially with the onset of congested states of traffic. To assess how the TMS 100 performed in different traffic states, CCIT planned to evaluate congested and free-flowing traffic situations. Using the Freeway Performance Measurement System (PeMS) database, the CCIT team identified peak hours and free-flow hours for the evaluation sites (Figure 16, Figure 17, and Figure 18).

The PeMS results showed heavy congestion for all three sites at around 4–5 p.m. This time period was not captured for the one-to-one video analysis, but it was looked at during the long-term analysis of comparing the TMS and AVC systems.

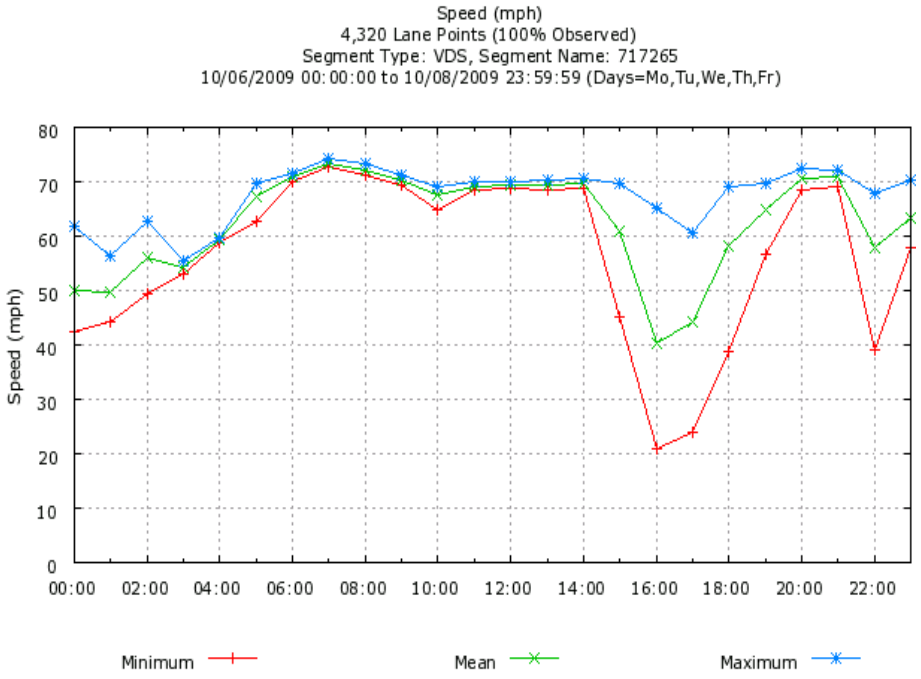


Figure 16. Station 098 traffic flow

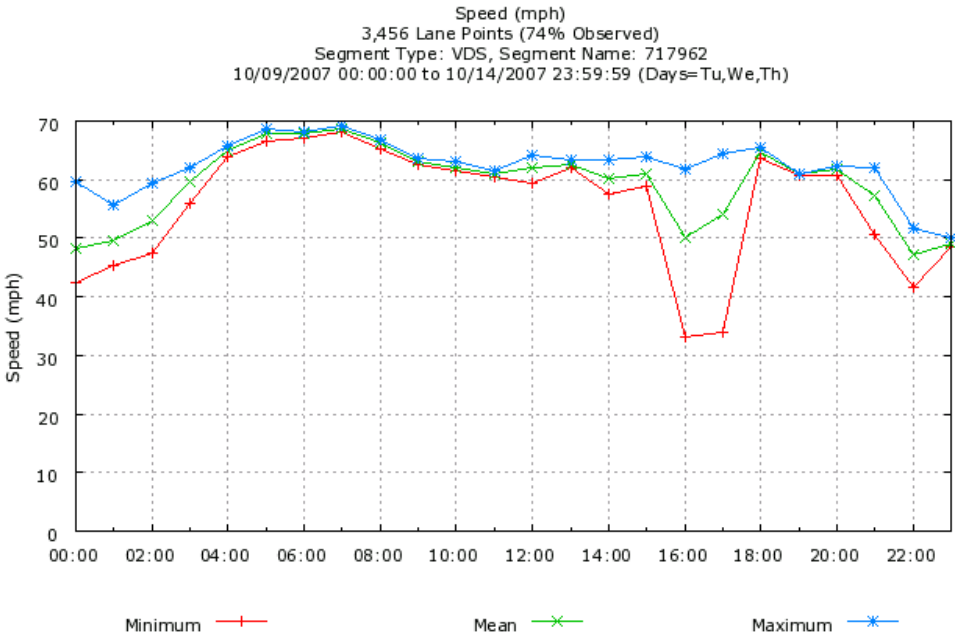


Figure 17. Station 037 traffic flow

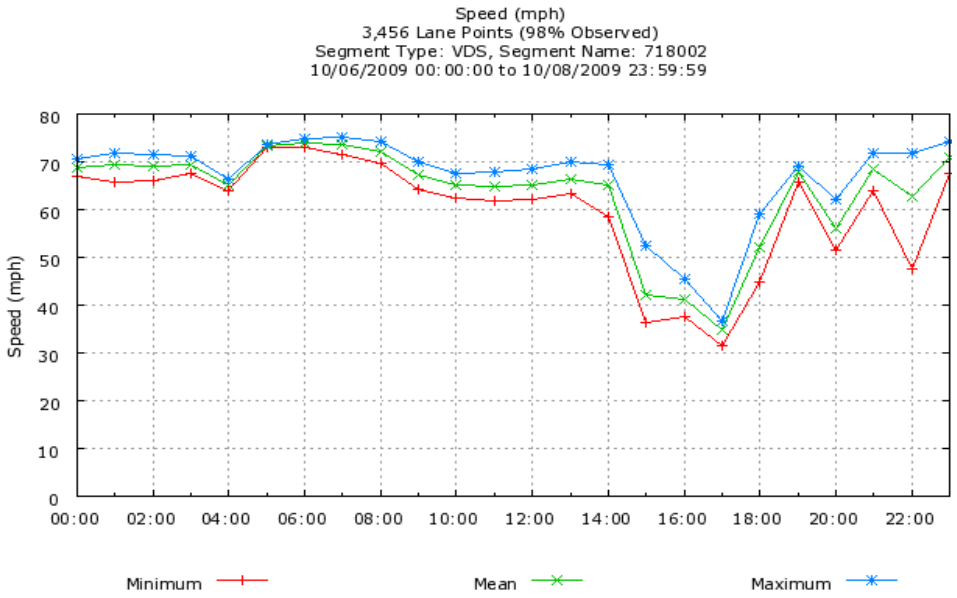


Figure 18. Station 040 traffic flow

5.1.3 VIDEO CAMERA PLACEMENT

Part of the site selection process was to find a safe and convenient location for the video cameras. For maximum safety and visibility, the ideal placement would have been atop an

overpass, but because of the physical constraints of the sites, the only viable option was along the freeway shoulder, a short distance away from the sensors. Caltrans supplied a truck with a boom lift to provide on-site safety and an elevated platform for recording.

Figure 19. Actual placement along freeway shoulder

5.2 DATA COLLECTION

The project used video recordings, PVR data, and aggregated data to evaluate the TMS 100. On-site videos were taken to validate the TMS PVR data. The video recordings were also used to ensure that the AVC data was accurate and robust and had come from highly calibrated system. It was important since the AVC data would be used as the ground-truth baseline. Data was collected remotely from the AVC and TMS systems to analyze the aggregated data.

5.2.1 VIDEO DATA COLLECTION AND PROCESSING

The team videoed each site to use as a one-to-one comparison for validating both the AVC data and the TMS 100 data. The video data helped researchers assess and identify different errors and provided insight about the system.

CCIT used a Cannon HV20A video camera connected to a laptop to record directly to hard disk using the HDVSplit program. This program records the video start time in the filename. To ensure clear image quality for data analysis, CCIT used a shutter speed of 1/500 (Figure 20).

Figure 20. Effects of shutter speed on image quality. Left: Shutter off. Center: 1/120 second shutter speed. Right: 1/500 second shutter speed.

Because the placement of the video camera was a slight distance away from the cabinets, to synchronize the camera and PVR data, the video camera operator and the AVC/TMS 100 operator communicated via cell phone to begin the data collection simultaneously. Starting both data recording processes simultaneously resulted in a low offset time. The TMS PVR data is recorded via the HyperTerminal using the Transfer > Capture Text option.

The video equipment did not have the capability to place timestamps within the recording. To easily compare the video to the AVC and TMS PVR data—which is marked with the actual time—timestamps were periodically inserted into the video by filming the current time on a cellular phone.

Both the PVR system and video-recording system had a slight lag between the start time and actual recording. To synchronize the data, an offset was calculated using the video timestamp and matching it to the vehicle combination. For example, if a sequence of vehicle lengths was observed, such as LV, SV, SV, LV, in both the PVR data and video data with the correct time intervals between the vehicles, the PVR timestamp would be adjusted to match the occurrence in the video.

To better analyze the data, high-resolution still images were extracted from the video at 30 frames per second (fps) using FFmpeg software. Lanes were analyzed individually. If it was observed that a vehicle crossed the loop detector, the classification of the vehicle and the frame in which it crossed the loop detector were noted. Vehicles were classified based on the number of axles, similar to the classification used by the AVC system. The frame number was converted into an image timestamp using the fps conversion:

$$Timestamp = \frac{Frame\#}{FPS}$$

The image timestamps and vehicle classifications were entered into a spreadsheet containing the PVR data. Table 1 shows a sample of the spreadsheet.

Table 1. Sample spreadsheet. The colored portion is PVR data; the non-colored portion is video data.

Lane	Length (feet)	Timestamp	Video Time	Video Seconds	Range of 30 Hz Image		Image	Video Lane	Video Class
4	71	02:13.0	00:17.2	17	495	525	510	4	9
3	32	02:17.6	00:21.6	22	645	675	652	3	6
4	54	02:19.9	00:23.9	24	705	735	715	4	6
5	64	02:27.6	00:31.6	32	945	975	944	5	9
4	84	02:31.5	00:35.5	36	1065	1095	1040	4	9

5.3 LONG-VEHICLE CLASSIFICATION CRITERIA

TMS classifies vehicles into two bins: bin 1 includes vehicles that are under 40 feet, and bin 2 indicates vehicles that are longer than 40.

AVC uses the Caltrans 15-bin vehicle classification system. Classes 1–14 are assigned according to the vehicle length and number of axles. These classes are divided into two main categories: short vehicle (SV) and long vehicle (LV). Class 15 is reserved for when a vehicle cannot be classified. For instance, under certain circumstances, such as when vehicles are changing lanes, driving offset from the center of the lane, or have trailers, the AVC system cannot classify the vehicle.

Table 2 shows how the AVC data was converted to the TMS two-bin classification system.

Table 2. Converting Caltrans vehicle classifications to TMS bins

Vehicle Bin	Vehicles Included in the Class	Lower Length Bound (<)	Upper Length Bound (< or =)	Class Equivalent
1	Passenger Vehicles	0 ft	13 ft	1 and 2
1	Single-unit Trucks	13 ft	40 ft	3, 4, 5, 6, and 7
2	Combination Trucks	40 ft	61 ft	8, 9, and 10
2	Multi-trailer Trucks	61 ft	120 ft	11, 12, 13, and 14

5.3.1 TMS 100 AND AVC DATA COLLECTION AND PROCESSING

Two types of data were collected from the AVC and TMS systems:

- PVR data (time stamped, lane-by-lane), as shown in Table 3 and Table 4
- Aggregated data (time stamped, lane-by-lane), as shown in Table 5 and Table 6

To analyze the data, it was first reorganized and excess information was removed. The vehicles were then classified as either LV (40 feet and longer) or SV. For the AVC system, this involved using an algorithm to identify classes 8–14 as LVs (see Table 2 for the AVC classes).

Table 7 shows the processed AVC data classified into two bins.

Table 3. Sample AVC PVR data

Date	Time	Array	Vehicle Number	Class	Speed (MPH)	LPL-Feet	Number of Axles
22-12-2009	00:02:05	Lane 3	1	9	39	55	5
22-12-2009	00:02:13	Lane 3	3	9	39	52	5
22-12-2009	00:02:17	Lane 3	5	9	32	57	5
22-12-2009	00:02:25	Lane 3	9	9	37	66	5
22-12-2009	00:02:36	Lane 3	13	9	38	56	5

Table 4. Sample TMS PVR data

Lane		Length (ft)		Speed (MPH)		Occupancy (ms)		Timestamp
lane	2	ft=	14	MPH	64	220	ms	01:56.2
lane	4	ft=	8	MPH	63	165	ms	01:56.1
lane	3	ft=	17	MPH	63	265	ms	01:56.2
lane	1	ft=	13	MPH	68	195	ms	01:56.7

Table 5. Sample aggregated AVC data collected directly from the system

	Class 1	Class 2	Class 3	Class 4	Class 5	Class 6	Class 7	Class 8	Class 9	Class 10	Class 11	Class 12	Class 13	Class 14	Class 15
00:00 N/B 1 (North)	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
N/B 2 (North)	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
N/B 3 (North)	0	21	4	0	2	1	1	2	1	0	0	0	0	0	1
N/B 4 (North)	10	747	107	1	12	7	0	0	31	0	1	0	0	10	4

Table 6. Sample 15-minute aggregated TMS data collected directly from the system. Each column shows lane-by-lane vehicle classification, where C1 is <40 feet and C2 is >40 feet.

Time	C1L1	C2L1	C1L2	C2L2	C1L3	C2L3	C1L4	C2L4	C1L5	C2L5	C1L6	C2L6
6:00	226	0	286	7	118	30	327	1	366	6	284	47
6:15	315	2	315	9	142	48	276	2	301	14	234	52
6:30	366	0	320	16	162	58	325	2	369	10	287	64
6:45	478	3	432	12	172	66	412	1	405	14	309	58
7:00	486	1	430	11	214	53	458	2	421	14	341	80
7:15	483	1	409	14	204	55	435	2	418	16	312	90
7:30	520	1	448	13	291	61	436	2	382	16	325	79
7:45	417	20	401	26	319	33	426	4	394	21	292	96

Table 7. Sample processed hourly-aggregated AVC data. Each column shows lane-by-lane vehicle classification, where C1 is <40 feet and C2 is >40 feet.

Time	C1L1	C2L1	C1L2	C2L2	C1L3	C2L3	C1L4	C2L4	C1L5	C2L5	C1L6	C2L6
6:00	673	1	899	32	382	118	789	2	1014	23	721	143
7:00	1645	6	1497	48	690	225	1471	7	1496	52	1171	254
8:00	1868	39	1680	92	1109	217	1849	10	1671	66	1238	368
9:00	1861	32	1575	132	895	357	2066	10	1545	139	1058	513
10:00	1804	4	1330	288	621	615	1655	8	1216	194	962	571

6 RESULTS

The results from the AVC validation were positive and within the expected parameters described by Caltrans. The results for evaluating the TMS 100 were compiled with limited data and a modified evaluation plan to account for the reduced staffing caused by the collision that occurred on the first day of the TMS evaluation.

6.1 PERFORMANCE MEASURE PARAMETERS FOR VIDEO COMPARISON

Various parameters were measured and analyzed while comparing the ground-truth video data for those 30-minute video recordings with AVC and TMS 100 data. It should be noted that since those 30-minute video recordings provide a very small sample size to be considered a global ground-truth, the ground-truth used for this analysis was AVC data that were collected around the clock. At the beginning, we used the 30-minute video recoding to make sure the AVC data is accurate and robust and the data is coming from a very highly calibrated system that would later on be considered as the ground-truth for our overall analysis. Table 8 shows the following measured parameters:

M_{GTS}—Ground-truth short-vehicle count (measured through the video camera)

M_{GTL}—Ground-truth long-vehicle count (measured through the video camera)

M_{SS}—Number of vehicles that were correctly classified as a short vehicle

M_{LL}—Number of vehicles that were correctly classified as a long vehicle

M_{SL}—Number of short vehicles classified as a long vehicle because of a system error

M_{LS}—Number of long vehicles classified as a short vehicle because of a system error

M_{SE}—Number of short vehicles erroneously counted as a long vehicle or not counted because of non-system-related, external errors

M_{LE}—Number of long vehicles erroneously counted as a short vehicle or not counted because of non-system-related, external errors

The external errors are caused by the following:

- Loop-detector cross-talk error
- AVC class 15 error
- Definition error

The following performance parameters were used to analyze the system.

Measure of accuracy level:

$$Average\ Total\ Correct\ Testing\_ = \frac{M_{SS}+M_{LL}}{M_{GTS}+M_{GTL}}$$

Rate for correct identification (long-vehicle classification) of given population:

$$Hit\_Rate = \frac{Total\_Correct\_LV\_Detection}{Testing\_LV\_Set\_Size} = \frac{M_{LL}}{M_{GTL}}$$

Rate for incorrect identification of given population:

$$Missed\_Rate = \frac{Total\_Missed\_LV\_Detection}{Testing\_LV\_Set\_Size} = \frac{M_{LS}+M_{LE}}{M_{GTL}}$$

Rate for misidentifying one population for the other:

$$False\_Alarm\_Rate = \frac{Total\_False\_Alarms}{Testing\_Alert\_Set\_Size} = \frac{M_{SL}}{M_{GTS}}$$

Rate for identifying accuracy level, distance away from true value (Saito, 2009):

$$Error\ Rate\ Ground\ Truth = \frac{Ground\ Truth - M_{LL}}{M_{GTL}}$$

Table 8: Sample of measured parameters

			Station Classification Output		
			SV	LV	Errors
Ground Truth	SV	M_{GTS}	M_{SS}	M_{SL}	M_{SE}
	LV	M_{GTL}	M_{LS}	M_{LL}	M_{LE}

6.2 AVC VALIDATION RESULTS

Because the AVC data was used as ground truth, it needed to be validated to ensure that it was accurate. Of the three sites chosen for evaluation, analysis was performed only on stations 098 and 037. While collecting video data at Station 040 NB, it was discovered that the wires leading to the piezo detectors were shorter than required, resulting in low line resistance in the system. This resistance caused abnormalities in the PVR data. The issue was resolved by adding lead wire and recalibrating the system.

Table 9, Table 10,Table 11 and Table 12 show the lane-by-lane AVC validation results. Only truck-driving lanes were analyzed.

Caltrans had reported that the AVC system would perform with accuracies above 95%. Station 037, a three-lane highway, had better results than station 098, a five-lane highway with more complex lane interaction. The results show that the accuracy of the AVC system varies by lane, with an overall accuracy of 90% or above. The AVC system tends to undercount vehicles when compared to the video data.

Table 9. AVC validation data: Station 037 northbound, lane 2

			Station 037 NB Lane 2					
			SV	LV	Errors	Class 15	Cross-talk	Missing
Ground Truth	SV	675	652	0	23	13	0	10
	LV	57	0	51	6	4	2	0

System Accuracy	96%
LV Hit Rate	89%
LV Miss Rate	11%
LV False Alarm	0%

For Station 037, lane 3 (Table 10), the AVC counted 375 SVs, but only 366 SVs were actually observed. This over-count occurred primarily when an LV neared the adjacent lane and its sensor mistakenly counted an SV.

Table 10. AVC validation data: Station 037 northbound, lane 3

			Station 037 NB Lane 3					
			SV	LV	Errors	Class 15	Cross-talk	Missing
Ground Truth	SV	366	365	0	1	1	0	0
	LV	157	4	153	0	0	0	0

System Accuracy	99%
LV Hit Rate	97%
LV Miss Rate	2%
LV False Alarm	0%

Table 11. AVC validation data: Station 098 eastbound, lane 5

			Station 098 EB Lane 5					
			SV	LV	Errors	Class 15	Cross-talk	Missing
Ground Truth	SV	303	291	0	12	3	3	6
	LV	16	0	15	1		1	0

System Accuracy	95%
LV Hit Rate	93%
LV Miss Rate	6%
LV False Alarm	0%

An undercount was observed at station 098, lane 4 (Table 12), which was caused by the class 15 errors counted at this station. Comparing the video data to the PVR data revealed many instances in which the AVC system missed passing SVs after recording a class 15 error. It was suspected that the system was recovering for a brief moment after reading a class 15 error and thus missed several vehicles.

Table 12. AVC validation data: Station 098 eastbound, lane 4

			Station 098 EB Lane 4					
			SV	LV	Errors	Class 15	Cross-talk	Missing
Ground Truth	SV	620	553	0	67	10	19	38
	LV	54	0	50	4	4	0	0
System Accuracy		89%						
LV Hit Rate		93%						
LV Miss Rate		7%						
LV False Alarm		0%						

6.3 TMS EVALUATION RESULTS

Assessing the TMS 100 consisted of performing a one-to-one comparison of the PVR data to the video data and then comparing the one-hour-bin aggregated TMS data to the AVC aggregated data for the long-term evaluation. The plan was to collect PVR data collection first. However, because of the accident (see 1), the team could only collect video and PVR data from station 098. The long-term evaluation (phase 2) comparing the TMS system to the AVC data continued but at a decelerated pace and with several modifications because of time constraints.

While comparing the TMS PVR data with the video, the results for Station 098 revealed a high number of external errors that were not associated with the TMS system. As a result, the first set of aggregated data could not be used for the evaluation.

The TMS algorithm parameters for lane-by-lane reference speed and length were adjusted to address the misclassifications. In addition, the threshold for LVs was increased from over 40 feet to over 50 feet. However, because of limited staffing, Caltrans could not calibrate the loop-detector sensors to address the cross-talk errors observed in Station 098.

The data was collected again with improved results. The TMS parameters were then fine-tuned, and a third set of aggregated data was collected.

The data was collected again with improved results. The TMS parameters were then fine-tuned, and a fourth set of aggregated data was collected over one month for long term analysis.

The aggregated data was collected over four time periods:

- Round 1: Two-week collection (March 14–27) using a 40-foot threshold
- Round 2: Two-day collection (May 17, 19, and 20); Day 1 used a 40-foot threshold, while Day 2 used a 50-foot threshold and TMS parameter adjustments to reference speed and length
- Round 3: One-day collection (May 26, 27, and 28) using a 50-foot threshold and further adjustments to the TMS reference speed and length parameters
- Round 4: One-month collection (March 2011) using a 50-foot threshold and further adjustments to the TMS reference speed and length parameters

The results are described in the following sections.

6.3.1 TMS PVR DATA COMPARISON RESULTS

Based on what we had learned from the video analysis performed during the AVC validation, the TMS evaluation was more in-depth in terms of identifying specific types of errors and analyzing the three truck lanes as a system in which each lane's sensor can interact with its adjacent lane. Table 13 and Table 14 show the results of the video analysis for Station 098.

The PVR analysis revealed two types of errors that were not associated with TMS 100 and the TMS algorithm:

1. Definition errors: Definition errors occurred in the process of converting the Caltrans 15-bin, axle-based vehicle classification (collected from AVC) to the TMS 2-bin, length-based format. Many vehicles approaching the 40-foot threshold (especially class 7 vehicles) were often observed as being slightly longer than 40 feet and thus classified as LV. This definition error occurred 45 times during the observation. It was also observed that the AVC PVR data had the average vehicle lengths for LVs higher than the selected threshold of 40 feet. Therefore, the team hypothesized that adjusting the threshold value for LVs above 40 feet would reduce this error.

2. Cross-talk errors: These errors were caused by LVs triggering a count in the adjacent lane. This cross-talk error was also seen in the AVC validation of Station 098, lane 3. Indications of this type of error were observed only in the three-lane system analysis where one lane would count an LV, and the adjacent lane would count an SV milliseconds after.

The high values for the hit rate and false alarm rate for Station 098 (see Table 14) indicate that the majority of the errors originated from the cross-talk. Because of the reduced Caltrans staffing, it was not possible to do an on-site adjustment to address the cross-talk issue.

Table 15 shows the results of comparing the AVC PVR and video data.

Table 13. Video data analysis results for Station 098

Station 098 Evaluation	Total	Lane 3	Lane 4	Lane 5
Total LV counted	**177**	**51**	**103**	**23**
Total LV identified as LV*	132	--	--	--
Total SV identified as LV*	45	--	--	--
Total cross-talk LV	**25**	**11**	**14**	**0**
LV caused cross-talk vehicles*	23	--	--	--
SV caused cross-talk vehicles*	2	--	--	--
SV identified as LV	**43**	**12**	**27**	**4**
LV identified as LV	**109**	**28**	**62**	**19**
TMS missed LV*	**1**	**1**	**0**	**0**
Total ground truth LV	**110**	**29**	**62**	**19**
*Missing LV: Lane 3, Class 8				

Table 14. Comparing TMS PVR and video data: TMS performance parameters for Station 098

TMS Performance Station 098	Total	Lane 3	Lane 4	Lane 5
LV accuracy*	61%	55%	60%	83%
Hit rate	99%	96%	100%	100%
Missed rate	1%	3%	0%	0%
False alarm rate	62%	79%	66%	21%
*From cross-talk	22%	38%	23%	0%
*From definition error	39%	40%	43%	21%

Table 15. Comparison of AVC PVR data and video data: Large vehicle distribution by class for lanes 3, 4, and 5

LV Distribution by Class for Lanes 3, 4, and 5	Ground Truth Count	AVC LV Counts and Lengths		
	Veh. Count	Veh. Count	Avg. Length	Stdev. Length
Class 8	**11**	**17**	54	3.4
Class 9	**90**	**82**	63	8.3
Class 10	**0**	**0**	N/A	N/A
Class 11	**2**	**2**	61	2.0
Class 12	**0**	**0**	N/A	NA
Class 13	**1**	**0**	N/A	N/A
Class 14	**6**	**6**	55	3.6
Class 15*	--	28	N/A	N/A
Total LV Counted	**110**	**107**	--	--
*AVC Class 15 counts are not included in the LV count. Error has unknown distribution between LVs and SVs.				

6.3.2 TMS AGGREGATED DATA COMPARISON RESULTS

After performing the one-to-one analysis, it was determined that increasing the threshold length to 50 feet would reduce some of the definition errors. It was also observed that class 15 errors might account for a significant number of over-counted LVs. The class 15 errors in the first round of collecting aggregated data had a 30:70 split between LVs and SVs. The second, third, and fourth evaluations show all-or-nothing assignments, with all class 15 vehicles classified as LVs. The upper bound has all the class 15 vehicles as LVs, and the lower bound has none of the class 15 vehicles as LVs.

6.3.2.1 FIRST ROUND OF AGGREGATED DATA COMPARISON: 1–2 WEEK RESULTS

The aggregated data collected in the first round during the weeks of March 14–27, 2010 was done prior to discovering that the loop-detector sensors and TMS parameters required calibration. Station 098 reflected the high error rates observed in the PVR analysis caused by over-counting the LVs, as explained in the PVR analysis. Station 037 also had similar high error rates. However, both these stations performed strongly in identifying SVs. The most promising station was 040, which had lower LV errors than SV errors.

Table 16, Table 17, and Table 18 show the hourly and daily errors for each evaluation site. Figure 21, Figure 22, and Figure 23 display the frequency of LV errors. Note the term bin refers to the aggregated LV errors in a 5, 10, or 15% range in Figs 21, 22, and 23 respectively. For example in Fig 20, Bin 0 contained the LV errors -2.5% to 2.5%. The results presented in the tables and figures are from 6:00 a.m. to 9:00 p.m. The hours between 9:00 p.m. and 6:00 a.m. had low-volume counts and were deemed unreliable.

The definition of error in each category (SV and LV) is as follows:

Error % = [(AVC volume – TMS volume)/AVC volume] x 100%

Table 16. Station 037, northbound, hourly and daily errors

	Station 037 NB Evaluation 1—Hourly Errors		
	Total NB	SV NB	LV NB
Average	-0.14%	1.76%	-27.73%
Stdev	2.55%	3.45%	25.12%
	Station 037 NB Evaluation 1—Daily Errors		
	Total NB	SV NB	LV NB
Average	-1.79%	0.03%	-25.10%
Stdev	5.80%	5.77%	9.82%

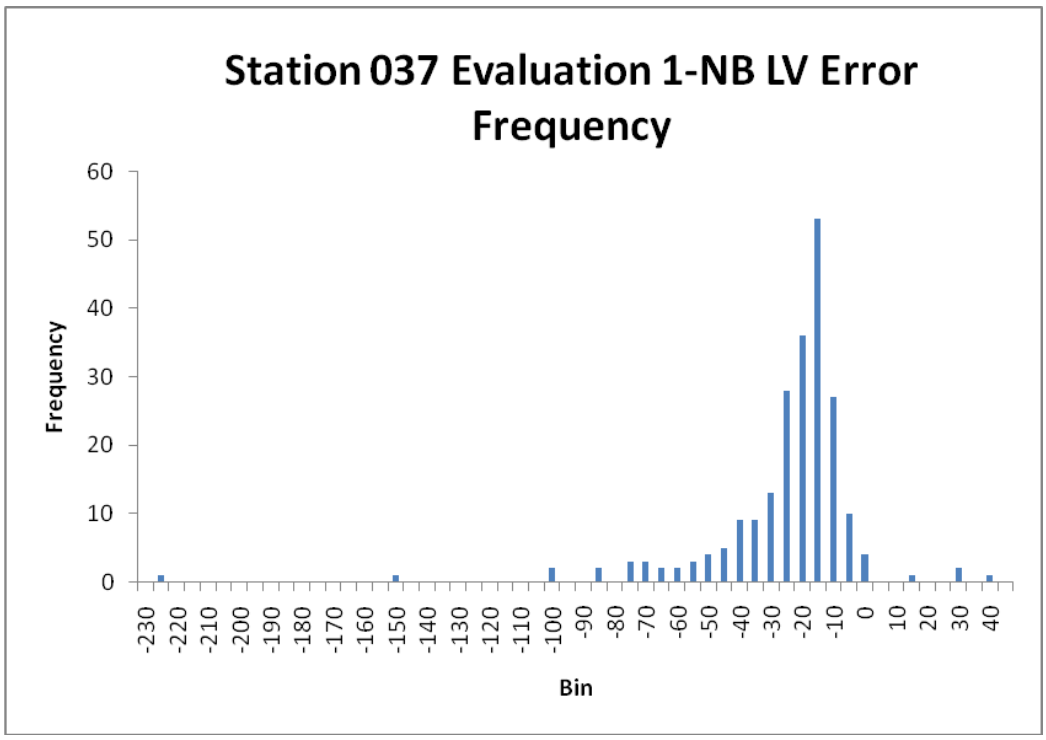


Figure 21. Station 037, northbound LV error frequency

Table 17. Station 040, southbound, hourly and daily errors

	Station 040 SB Evaluation 1—Hourly Errors		
	Total SB	SV SB	LV SB
Average	16.12%	16.81%	3.12%
Stdev	4.52%	4.85%	15.96%
	Station 040 SB Evaluation 1—Daily Errors		
	Total SB	SV SB	LV SB
Average	14.39%	15.02%	2.75%
Stdev	5.69%	5.75%	4.51%

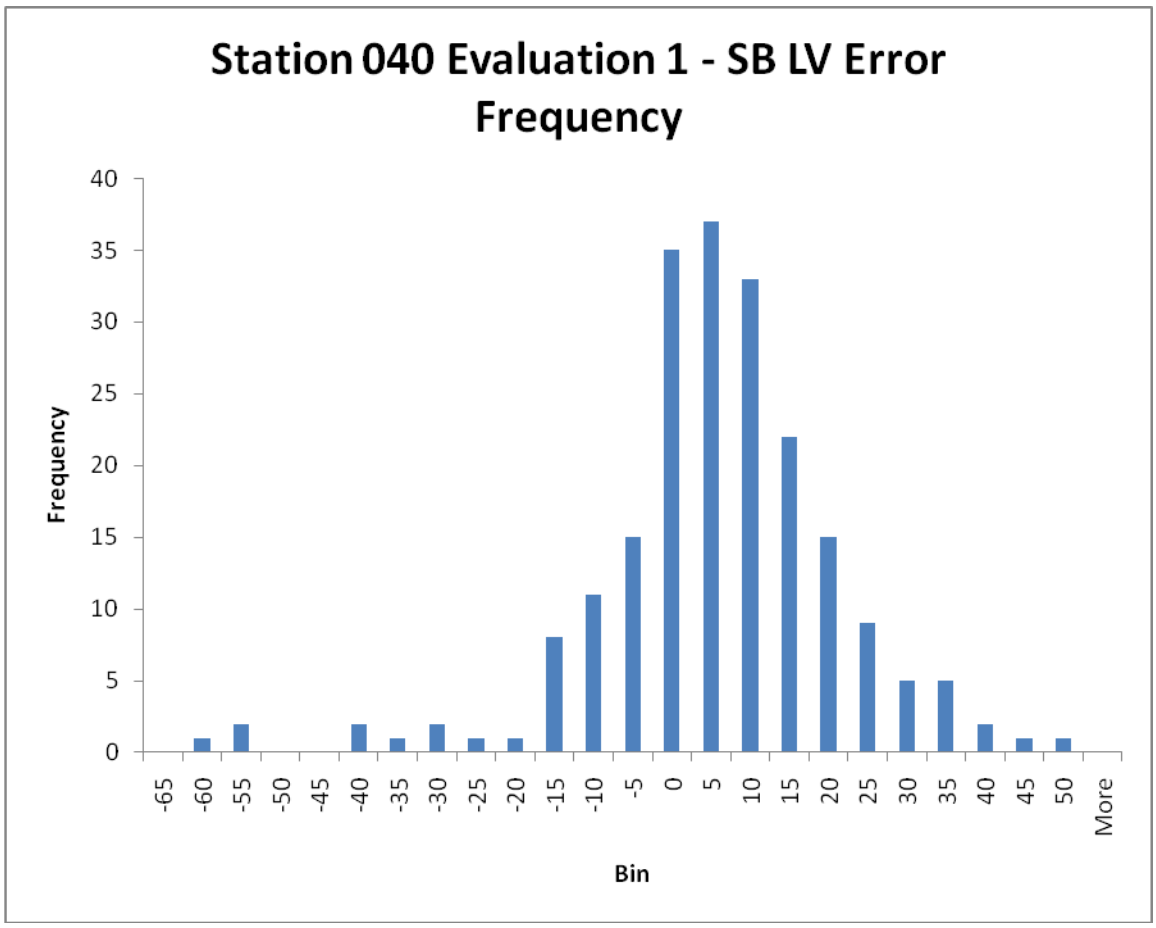


Figure 22. Station 040, southbound LV error frequency

Table 18. Station 098, eastbound, hourly and daily errors

	Station 098 Evaluation 1—Hourly Errors		
	Total EB	EB SV	EB LV
Average	-1.68%	0.18%	-84.61%
Stdev	4.27%	4.49%	39.97%
	Station 098 Evaluation 1—Daily Errors		
	Total EB	EB SV	EB LV
Average	-2.63%	-0.90%	-77.26%
Stdev	3.43%	3.31%	11.31%

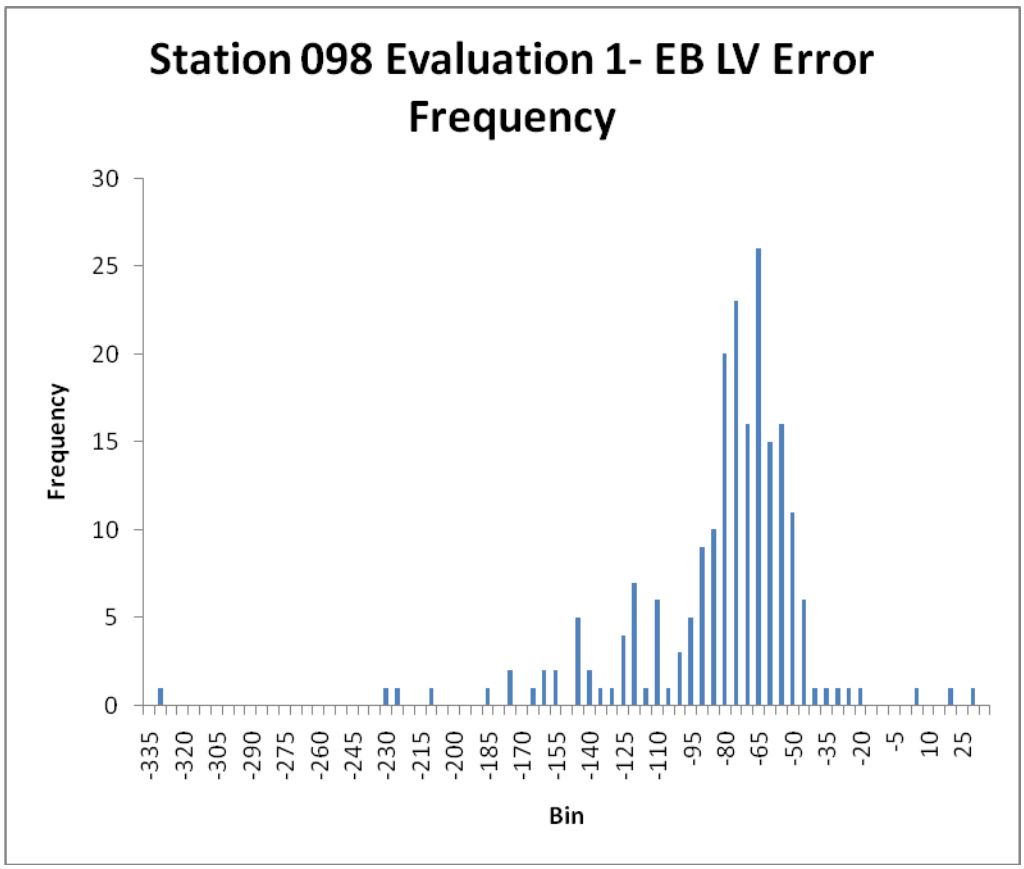


Figure 23. Station 098, eastbound LV error frequency

6.3.2.2 SECOND ROUND OF AGGREGATED DATA COMPARISON: TWO-DAYS RESULTS

As part of the second evaluation, the TMS software parameters for lane-by lane reference speed and length were adjusted to address the issues with over-counting LVs. This evaluation occurred over a period of two days, spanning May 17, 19, and 20, 2010. The first day used a 40-foot threshold for LVs. For the second day, the threshold was increased to 50 feet. The results for this analysis are again from 6:00 a.m. to 9:00 p.m.

The following tables show the lower-bound and upper-bound errors of the aggregated data over a two-day period for each evaluation site. On the first day, the TMS threshold parameter was set to 40 feet; on the second day, the threshold was increased to 50 feet.

In the results for Station 037, the second day had noticeable improvements after the length threshold had been adjusted, as shown in Table 19 and Table 20. Similar improvements occurred at Station 098, as shown in Table 23 and Table 24.

Table 19. Station 037, May 17, 2010

	Station 037 NB Evaluation 2—Hourly Errors, Lower Bound (5/17/10)		
	NB Total	NB SV	NB LV
Average	-0.93%	1.38%	-21.24%
Stdev	0.37%	0.94%	11.52%
	Station 037 NB Evaluation 2—Hourly Errors, Upper Bound (5/17/10)		
	NB Total	NB SV	NB LV
Average	-0.42%	1.38%	-14.66%
Stdev	0.33%	0.94%	7.33%

Table 20. Station 037, May 20, 2010

	Station 037 NB Evaluation 2—Hourly Errors, Lower Bound (5/20/10)		
	Total NB	NB SV	NB LV
Average	-0.92%	-0.06%	-9.07%
Stdev	0.47%	0.66%	7.55%
	Station 037 NB Evaluation 2—Hourly Errors, Upper Bound (5/20/10)		
	Total NB	NB SV	NB LV
Average	-0.37%	-0.06%	-2.61%
Stdev	0.40%	0.66%	5.27%

Station 040 had good results in the initial two-week evaluation. In the second evaluation, the number of errors did not change significantly, as shown in

Table 21 and Table 22. This might be attributed to better TMS calibration at Station 040.

Table 21. Station 040, May 17, 2010

	Station 040 SB Evaluation 2—Hourly Errors, Lower Bound (5/17/10)		
	Totals	SV	LV
Average	3.76%	3.76%	4.87%
Stdev	1.84%	1.90%	8.77%
	Station 040 SB Evaluation 2—Hourly Errors, Upper Bound (5/17/10)		
	Totals	SV	LV
Average	5.15%	5.15%	4.87%
Stdev	1.43%	1.90%	9.95%

Table 22. Station 040, May 19, 2010

	Station 040 SB Evaluation 2—Hourly Errors, Lower Bound (5/19/10)		
	Totals	SV	LV
Average	16.30%	5.77%	5.73%
Stdev	2.41%	2.48%	4.50%
	Station 040 SB Evaluation 2—Hourly Errors, Upper Bound (5/19/10)		
	Totals	SV	LV
Average	18.49%	6.44%	5.73%
Stdev	1.85%	2.48%	10.97%

Table 23. Station 098, May 17, 2010

	Station 098 EB Evaluation 2—Hourly Errors, Lower Bound (5/17/10)		
	Total	SV	LV
Average	-4.02%	-0.57%	-104.81%
Stdev	1.05%	0.43%	35.39%
	Station 098 EB Evaluation 2—Hourly Errors, Upper Bound (5/17/10)		
	Total	SV	LV
Average	-3.54%	-0.57%	-73.63%
Stdev	0.93%	0.43%	20.32%

Table 24. Station 098, May 19, 2010

	Station 098 EB Evaluation 2—Hourly Errors, Lower Bound (5/19/10)		
	Totals	SV	LV
Average	-3%	-2%	-72%
Stdev	2%	1%	24%
	Station 098 EB Evaluation 2—Hourly Errors, Upper Bound (5/19/10)		
	Totals	SV	LV
Average	-3%	-2%	-21%
Stdev	1%	1%	14%

6.3.2.3 THIRD ROUND OF AGGREGATED DATA COMPARISON: ONE-DAY RESULTS

The third evaluation period reflects further adjustments to the TMS length parameter. The following tables show the lower-bound and upper-bound errors of the aggregated data over a one-day period for each evaluation site, either May 26, 27, or 28, 2010. Once again, the period of analysis was from 6:00 a.m. to 9:00 p.m.

The errors for stations 037 (Table 25) and 040 (Table 26) did not differ significantly. However, Station 098 (Table 27 and Table 28) The attached *TMS 100 User Guide* provides information on setting up the units and modifying the parameters.

Table 25. Station 037, May 26, 2010

	Station 037 NB Evaluation 3—Hourly Errors, Lower Bound (5/26/10)		
	Total	SV	LV
Average	-1.1%	-0.8%	-4.3%
Stdev	0.4%	1.0%	10.0%
	Station 037 NB Evaluation 3—Hourly Errors, Upper Bound (5/26/10)		
	Total	SV	LV
Average	-0.5%	-0.8%	2.1%
Stdev	0.4%	1.0%	8.4%

Table 26. Station 098, May 26, 2010

	Station 098 EB Evaluation 3—Hourly Errors, Lower Bound (5/26/10)		
	Total	SV	LV
Average	5.3%	4.9%	9.7%
Stdev	2.2%	2.3%	6.0%
	Station 098 EB Evaluation 3—Hourly Errors, Upper Bound (5/26/10)		
	Total	SV	LV
Average	6.0%	4.9%	20.0%
Stdev	1.6%	2.3%	12.0%

Table 27. Station 098, May 27, 2010

	Station 098 EB Evaluation 3—Hourly Errors, Lower Bound (5/27/10)		
	Totals	SV	LV
Average	-3.4%	-2.4%	-51.3%
Stdev	1.6%	1.4%	29.3%
	Station 098 EB Evaluation 3—Hourly Errors, Upper Bound (5/27/10)		
	Totals	SV	LV
Average	-2.6%	-2.4%	-9.4%
Stdev	1.5%	1.4%	9.6%

Table 28. Station 098, May 28, 2010

	Station 098 EB Evaluation 3—Hourly Errors, Lower Bound (5/28/10)		
	Totals	SV	LV
Average	-2.8%	-1.6%	-61.6%
Stdev	1.9%	1.8%	41.0%
	Station 098 EB Evaluation 3—Hourly Errors, Upper Bound (5/28/10)		
	Totals	SV	LV
Average	-1.7%	-1.6%	-5.6%
Stdev	1.8%	1.8%	10.6%

6.3.2.4 FOURTH ROUND OF AGGREGATED DATA COMPARISON: ONE-MONTH RESULTS

The fourth evaluation period reflects longer evaluation periods. The following data shows the lower-bound and upper-bound errors of the aggregated data over a one-month period for each evaluation site excluding weekends in March 2011 because of low LV counts. Once again, the period of analysis included data from 6:00 a.m. to 9:00 p.m. only. The outliers were removed from the data analysis and were not presented below.

The data was collected in one hour aggregated bins. Therefore the hourly errors in the following tables were calculated using every bin in the aggregated data as an error value. The daily errors were calculated from a day's worth of aggregated data from the one hour data bins; there is only one error value per day. The daily hourly average errors were computed by taking all of the hourly errors in that day and averaging them together to produce one error value. This error value is different than the daily error because the daily error was comprised of a single error value while the daily hourly error was comprised of an average of 15 hourly errors in a day. Therefore, the number of data points incorporated in the averages for the tables below is as followed: 23 errors for the daily averages, 23 errors for the daily hourly averages, and 345 errors for the hourly averages.

Tables 29, 30, 31 presented the computed averages, standard deviations, and peak averages using hourly, daily, daily hourly average errors for the 2 sites. The hourly averages produced wider distributions with less precise averages than the previous two methods. This suggested that hourly data contained too many deviant errors which were large, but not outliers; an inappropriate statistical method for longer studies. From the tables, the daily and daily hourly error averages produced roughly the same averages and distributions. Therefore, these methods would be a viable option for further study. With smaller standard deviations, multiple data collections spanning many months using the two different daily error statistics would obtain similar results without significant deviations barring unforeseen circumstances. The averages for the SV data were small (less than 10% in absolute terms) and within Caltrans limits. However, all SV error data contained systematic error which is occurrence of some internal or external characteristic found in all the data shifting the observed mean from the actual mean and may even cause the distribution to be altered as well. The LV errors we more normal (except station 037 SB) in nature, centered around 0% error, which was a vast improvement from the previous rounds worth of collected data. Therefore the SV counts would require a multiple factor to correct for the systematic behavior while the LV counts would be ready for data analysis as obtained from the field.

Figures 24-29 show hourly error frequencies or distributions using only the lower-bound LV data.

Figures 24, 26, and 28 show the lower bound error frequencies in a histogram. The major observation was that the LV error data was roughly normal in the distributions; a vast improvement from previous methods which had no apparent shape. The majority of data was contained within ±25% from the calculated averages for each graph. Only a few hourly error points were close to 100% error in either direction and excluded from the analysis because of their obvious outlier status. Therefore the collected data was improved significantly from the previous rounds.

Figures 25, 27, and 29 show how the LV lowers bound error data varied by time of day. The graphs contained multiple points including: data points (small blue squares), undercount mean (sky blue bar), over count mean (green triangle), absolute mean (red circle), and regular mean (orange diamond). The over count mean averaged all of the error values which were negative (less than 0) while the undercount averaged all of the positive (greater than 0) errors. The absolute average ignored the errors' sign when averaged while the regular mean did not ignore the sign. Also each hour contained 23 error points because there were 23 weekdays in the data set.

From the three figures, the absolute errors did not vary substantively by hour. However, the peak hours had slightly larger absolute errors compared to the non-peak hour errors. This can

be explained by the TMS dependence on the loop detectors for accurate vehicle counts, but may also be from other location dependent parameters. Therefore the system was less precise during peak hours, but not drastically. Another observation from the figures was that the peak hour errors had significantly wider spreads compared to the non-peak hour errors. Also most of the absolute errors were within 25% error and the regular average errors were closer to 0% error still. The non-peak hours' distributions were similar in terms of the spread and the multiple averages. More data still needs to be collected to understand the reasons behind the error disparity between non-peak hours and peak hours as well as why some hours had a narrow spread and others larger ones.

Note the term bin refers to the aggregated LV errors in a 10% range in Figs 24, 26, and 28 respectively. For example in Fig 24, Bin 0 contained the LV errors -5% to 5%.

Table 29. Station 037 NB, March 2011

Station 037 NB Evaluation 4, Lower Bound LV (Weekdays March 2011)			
	Hourly Errors	**Daily Errors**	**Daily Hourly Average**
Average	-6.76%	-6.86%	-9.43%
Stdev	14.90%	2.54%	3.71%
Peak Average	-9.73%	N/A	N/A
Station 037 NB Evaluation 4, Upper Bound LV (Weekdays March 2011)			
	Hourly Errors	**Daily Errors**	**Daily Hourly Average**
Average	6.13%	4.49%	5.10%
Stdev	15.07%	4.28%	5.17%
Peak Average	10.11%	N/A	N/A
Station 037 NB Evaluation 4, SV (Weekdays March 2011)			
	Hourly Errors	**Daily Errors**	**Daily Hourly Average**
Average	-2.92%	-2.72%	-2.92%
Stdev	5.75%	1.53%	1.53%
Peak Average	-5.12%	N/A	N/A

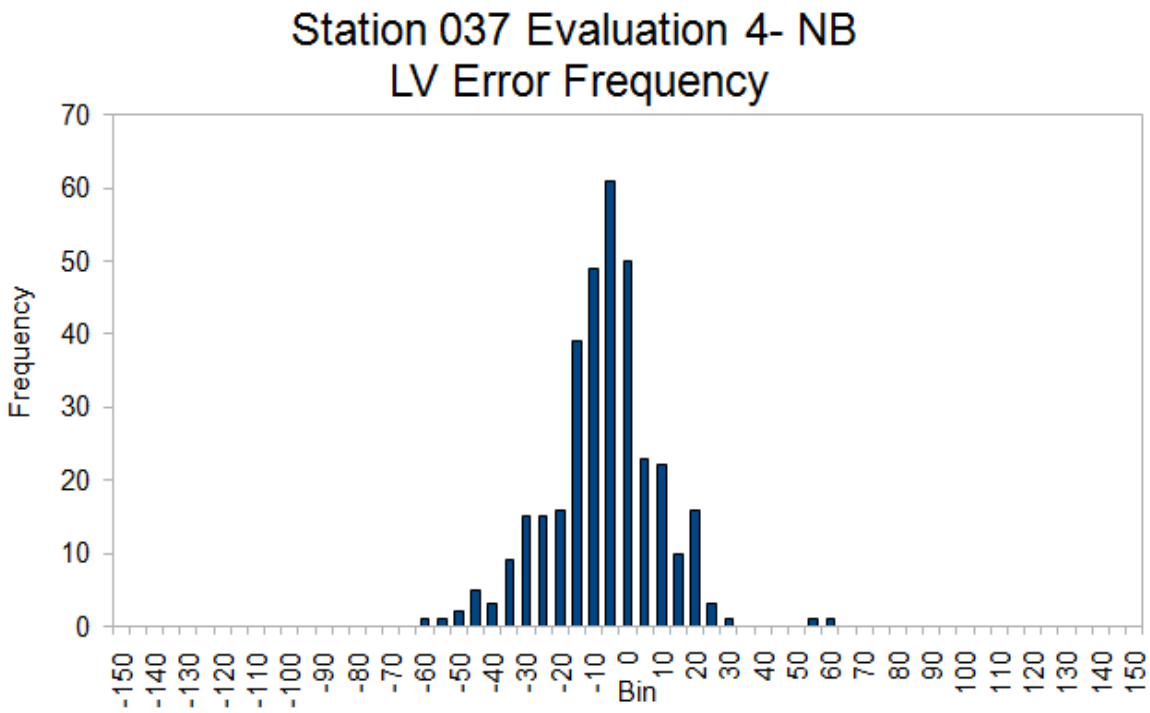


Figure 24. Station 037, NB LV error frequency

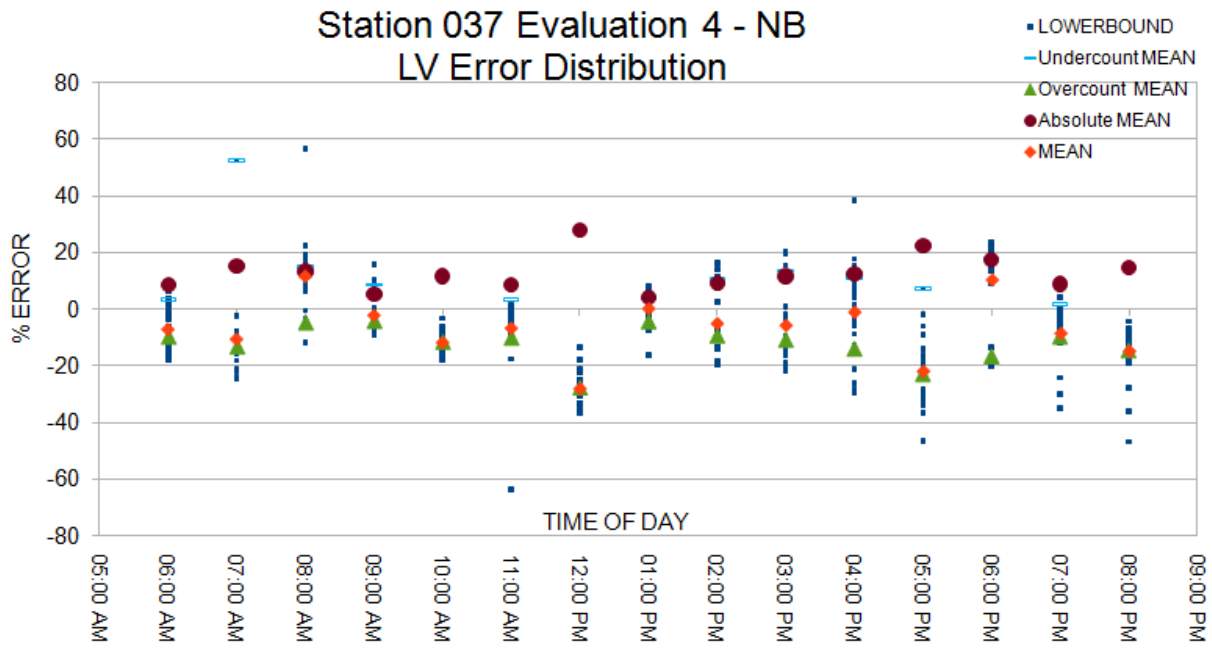


Figure 25. Station 037, NB LV error distribution

Table 30. Station 037 SB, March 2011

Station 037 SB Evaluation 4, Lower Bound LV (Weekdays March 2011)			
	Hourly Errors	**Daily Errors**	**Daily Hourly Average**
Average	2.23%	1.94%	1.11%
Stdev	10.45%	3.76%	4.15%
Peak Average	1.67%	N/A	N/A
Station 037 SB Evaluation 4, Upper Bound LV (Weekdays March 2011)			
	Hourly Errors	**Daily Errors**	**Daily Hourly Average**
Average	17.93%	17.99%	17.12%
Stdev	9.03%	3.43%	4.53%
Peak Average	15.79%	N/A	N/A
Station 037 SB Evaluation 4, SV (Weekdays March 2011)			
	Hourly Errors	**Daily Errors**	**Daily Hourly Average**
Average	-5.80%	-5.55%	-5.81%
Stdev	5.68%	2.07%	1.99%
Peak Average	-5.73%	N/A	N/A

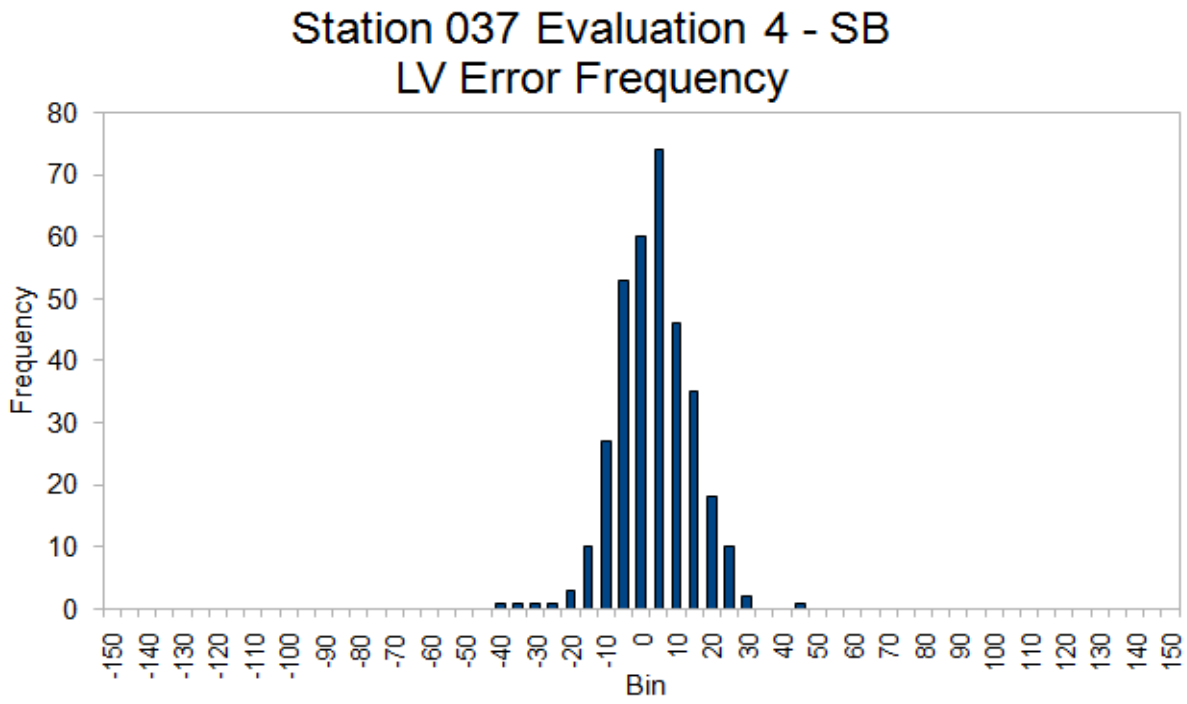


Figure 26. Station 037, SB LV error frequency

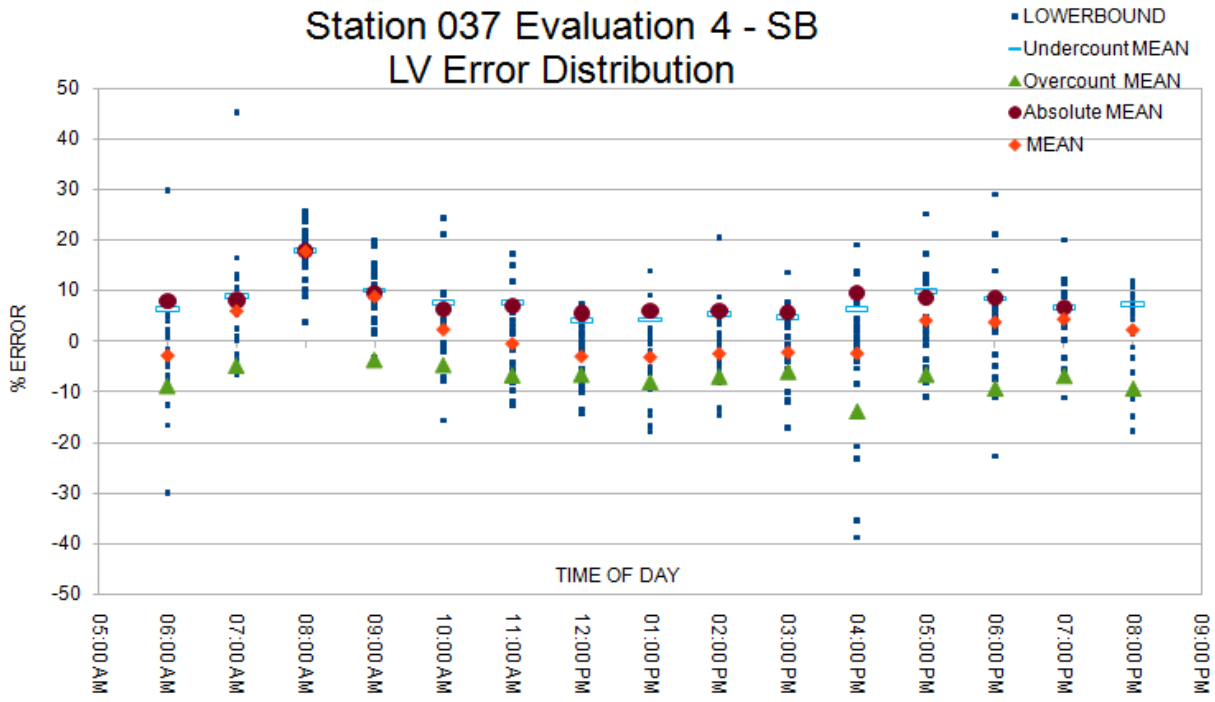


Figure 27. Station 037, SB LV error frequency

Table 31. Station 040 NB, March 2011

Station 040 NB Evaluation 4, Lower Bound LV (Weekdays March 2011)			
	Hourly Errors	**Daily Errors**	**Daily Hourly Average**
Average	-2.28%	-0.10%	-2.06%
Stdev	18.51%	4.25%	5.55%
Peak Average	-4.16%	N/A	N/A
Station 040 NB Evaluation 4, Upper Bound LV (Weekdays March 2011)			
	Hourly Errors	**Daily Errors**	**Daily Hourly Average**
Average	9.93%	10.71%	10.22%
Stdev	18.40%	4.53%	4.74%
Peak Average	10.48%	N/A	N/A
Station 040 NB Evaluation 4, SV (Weekdays March 2011)			
	Hourly Errors	**Daily Errors**	**Daily Hourly Average**
Average	5.56%	5.67%	5.69%
Stdev	6.16%	5.55%	0.73%
Peak Average	3.77%	N/A	N/A

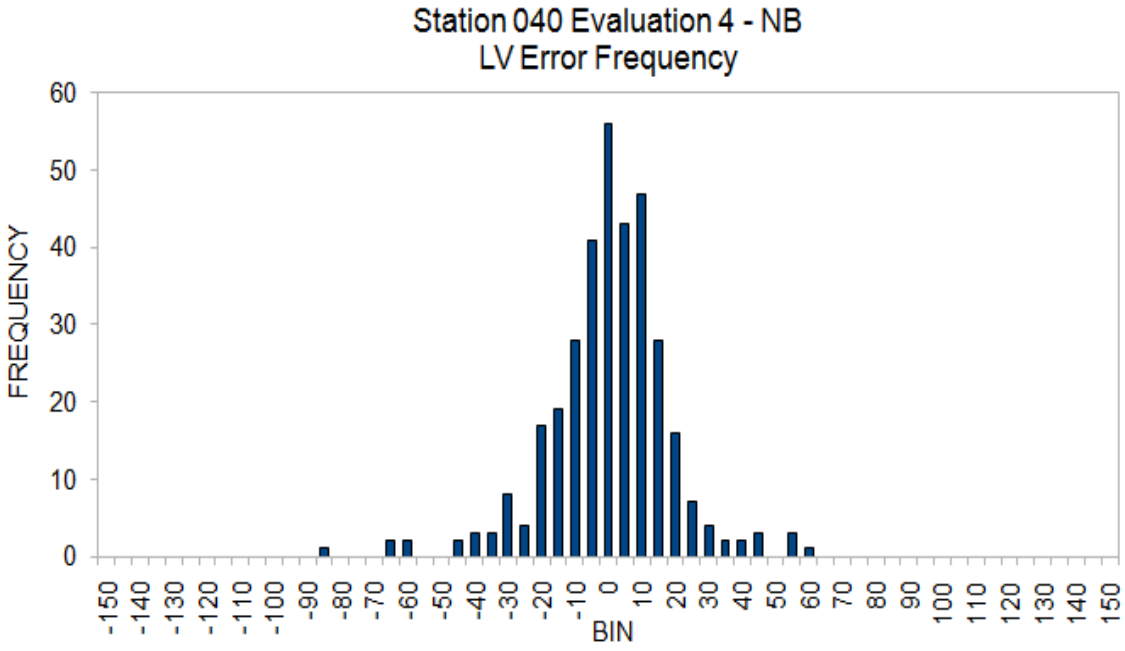


Figure 28. Station 040, NB LV error frequency

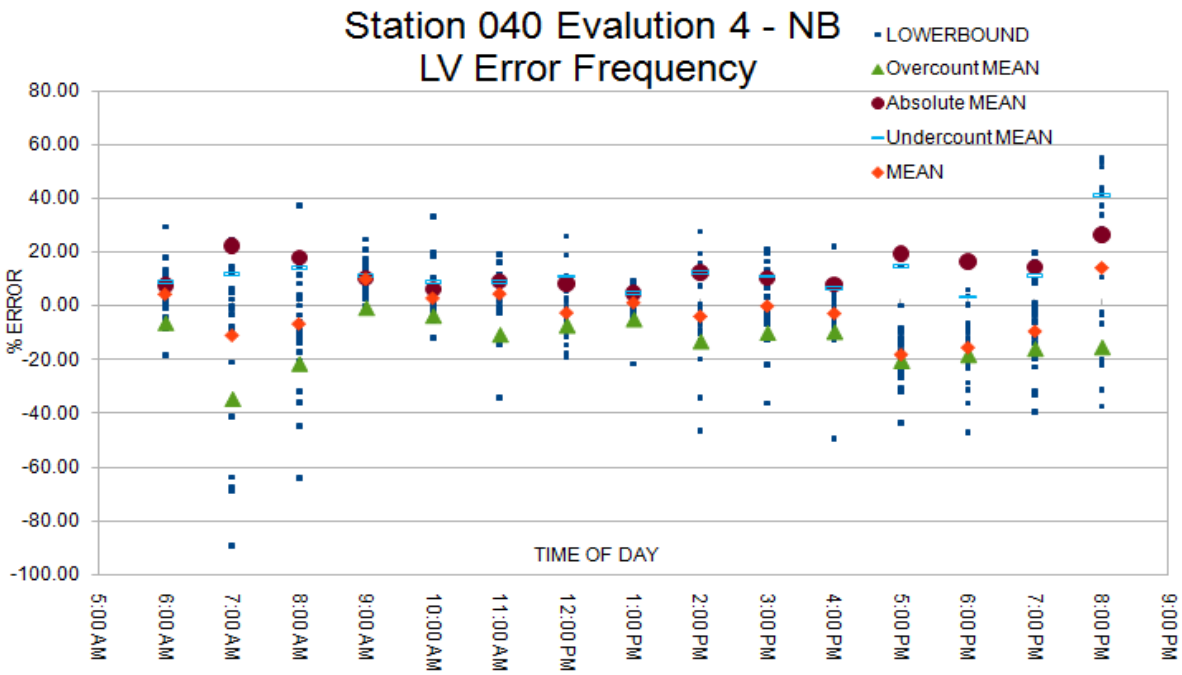


Figure 29. Station 040, NB LV error distribution

After referring to the previous evaluation rounds of error analysis, the fourth round of data collection produced normal LV frequency data centered near 0% error (expect Station 37 SB); a significant improvement in accuracy from previous rounds which had no apparent shape. The range of the hourly errors decreased significantly from the previous evaluations; a significant improvement in precision. The two different daily errors had smaller average spreads still. The SV errors and LV Station 037 SB errors contained systematic error shifting the mean error measured and possibly the spread as well, but not outside of Caltrans range tolerances.

Overall, the TMS system, after further calibrations with a longer LV transition length was shown to provide accurate and reliable LV and SV counts over the course of a month. Therefore the system was performing within its expected operation and further calibration would not be needed unless more precise data was needed.

7 CONCLUSION

While this limited deployment project had its challenges, it also had many successes. The Caltrans team was able to install 20 working TMS units in the field (see 2), despite the constraints and challenges. The TMS unit proved versatile and offered a solar solution when there were power issues at a site.

A series of unexpected circumstances, in addition to funding and staffing constraints, limited the evaluation to three sites. The CCIT researchers and Caltrans personnel were involved in a serious multicar collision while collecting video data. As a result, the only video data collected was at Station 098. The video data analysis for Station 098 revealed that the loop-detector sensors in that station were not calibrated, so the data was not usable. Three weeks of AVC and TMS data were collected after the incident as well as one month worth of data in 2011. The initial comparison of TMS and AVC (ground-truth data) showed large values of error due to the poor calibration of TMS units. However, the team was able to complete two more rounds of comparing AVC and TMS data, with the TMS parameters calibrated and fine-tuned after each round. The third round consisted of one day of collected data. Because the TMS parameters were then calibrated properly for the site, better data was collected. The final round consisted of one month of collected data in early 2011. The hourly errors for LVs overlapped near 0% error with a narrower distribution than the previous evaluations; an improvement in accuracy and precision. The two daily errors produced similar average ranges as well as narrower distributions compared to the hourly errors. However, weekend errors varied more than weekday's errors and had wider distributions because of low LV counts and were ignored. With more error data, it was determined that SV and Station 037 SB LV counts incorporated systematic error while the other two LV data groups were normal requiring further calibration on the systematic error locations to extract the accurate vehicle count. Therefore most LV error data will become more accurate and precise as more weekday data is collected. Looking into the data's variance by time of day, it was shown that the peak hours were slightly more error prone than the rest of the day, but the underlying cause was indeterminate. Overall, the TMS varied slightly from the time of day the data was collected. The comparison results showed that TMS performance matches Caltrans expectations and the results were improved with longer evaluation times and will improve with longer intervals and further calibration of the AVC and TMS.

The TMS unit was adaptable to varying situations. The installation sites chosen ranged from a simple three-lane highway to a six-lane highway with on-ramps. With the ability to adjust input parameters from a remote location, the TMS unit can be calibrated with ease to adapt to these physical situations and other dynamic ones. For instance, if the flow of traffic is known to shift between seasons, input parameters can be adjusted remotely to better reflect what is on the

road at that time. With the AVC system adjacent to several TMS locations, it is also possible to validate the changed parameters.

The unit's ability to be calibrated was matched by the success of its calibration, as seen during the adjustments made between the four evaluation periods. Adjusting the classification threshold and effective length lowered the error rates.

Many lessons were learned from the initial poor results from the first round of evaluation. The analysis of the errors at Station 098 led to the adjustments made during the second, third, and fourth evaluations, which improved system performance. The errors observed showed the connection between the TMS unit and the equipment in the field. Ensuring that the loop-detector sensors are calibrated is just as important as adjusting the TMS software parameters. It also demonstrated that the calibration process is iterative and that both systems might need to be adjusted simultaneously.

Lastly, our analysis supports that the system can provide a viable cost-effective solution for Caltrans to assess truck-traffic volume based on these characteristics:

- Ability to use the existing, widely deployed, single-loop detectors and infrastructure
- Ease of installation
- Capability of using various communication channels
- Remote access

8 REFERENCES

Carlson, B. Clearing the congestion: vision makes traffic control intelligent. Advanced Imaging, February 1997, pp. 54–57.

Darter, Michael T., Stephen M. Donecker, Kin S. Yen, Bahram Ravani, and Ty A. Lasky. Overview of Caltrans District 10 IRIS Demonstration Design, AHMCT Research Report UCD-ARR-07-12-31-02, December 31, 2007.

Dillenburg, J., Lain, C., Nelson, P.C., Rorem, D. Design of the ADVANCE traffic information center. Proceedings of the 1995 Annual Meeting of ITS AMERICA, pp. 321–328.

Harlow, Charles and Shiquan Peng. Automatic vehicle classification system with range sensors. Transportation research part C: Emerging Technologies, Volume 9, Issue 4, , August 2001, pp. 231–247. www.sciencedirect.com/science, visited June 4, 2009.

Harvey, Bruce A., Glenn H. Champion, Steven M. Ritchie, and Craig D. Ruby. Accuracy of truck traffic monitoring equipment. Technical report GTRI Project A-9291, Communications and network division, Information Technology and telecommunications laboratory, Georgia Tech Research Institute, June 1995. www.fhwa.dot.gov/ohim/atme/atme.htm, visited June 30, 2009.

Juba, M. Succeeding with video detection. Traffic Technol. Int., Oct/Nov, 1996, pp. 33–36.

Kell, J. H., Fullerton, I. J., and Mills, M.K. Traffic Detector Handbook, FHWA-IP-90-002, Federal Highway Administration, 1990.

Kistler Instruments Corporation, Piezo electric force transducers. Design & Use, Amherst, NY, 2000.

Klein, L. A. Sensor Technologies and Data Requirements for ITS. Norwood, MA: Artech House, 2001, p. 549.

Kunigahalli, R. A multidimensional geometric approach to detection of freeway congestion. Proceedings of the 1995 Annual Meeting of ITS AMERICA, pp. 597–604.

Lin, Wei-Hua, Joy Dahlgren, and Hong Huo. Enhancement of Vehicle Speed Estimation with Single Loop Detectors. Journal of the Transportation Research Board, No. 1870, TRB, National Research Council, Washington, D.C., 2004, pp. 147–152.

Lu, Y. Vehicle Classification Using Infrared Image Analysis. ASCE Journal of transportation Engineering. Vol. 118. No. 2. March/April, 1989, pp. 223–240.

Martin, Peter T., Yuqi Feng, and Xiaodong Wang. Detector technology evaluation. www.mountain-plains.org/pubs/html/mpc-03-154/pg1.php, November 2003.

Middleton, Dan and Rick Parker. Initial evaluation of selected detectors to replace inductive loops on freeway. FHWA, TX-00/1439-7, April 2000.

Mimbela , Luz Elena Y. and Lawrence A. Klein. A summary of vehicle detection and surveillance technologies used in intelligent transportation systems. Vehicle detector clearing house, New Mexico State University, Fall 2000.

Minnesota Department of Transportation. Field Test of Monitoring of Urban Vehicle Operations Using Non-intrusive Technologies, Final Report. SRF Consulting Group, INC., MN, May 1997.

Minnesota Department of Transportation. NIT Phase 2 Evaluation of Non-intrusive Technologies for Traffic Detection, Final Report. St. Paul, MN, September 2002.

Nojima, A., Iwata, Y., and Hirano, K. An in-vehicle information system using simple deformed map displays and two-way infra-red beacons. Proceedings of the 1995 Annual Meeting of ITS AMERICA, pp. 201–206.

Nooralahiyan, A. Y., et al. Trial of Acoustic Signature Analysis for Vehicle Classification. Transportation research, C. Vol. 5. No. 314. 1997, pp 165–177.

Pursula, M. and Pikkarainen, P. A Neural Network Approach to Vehicle Classification with Double Inductive Loops. Proceedings of the 17th ARRB conference, Part 4, 1994, pp. 29–44.

Ritchie, S. G., Abdulhai, B., Parkany, A. E., Sheu, J. B., Cheu, R. L., and Khan, S. I. A comprehensive system for incident detection on freeways and arterials. Proceedings of the 1995 Annual Meeting of ITS AMERICA, pp. 617–622.

Rouphail, N. M., Dutt, N. Estimating travel-time distributions for signalized links: model development and potential its applications. Proceedings of the 1995 Annual Meeting of ITS AMERICA, pp. 623–632.

Safaai-Jazi, Ahmad, Siamak A. Ardekani, and Majid Mehdikhani. A low-cost fiber optic weigh in motion sensor. SHRP-ID/UFR-90-002, Strategic Highway Research Program, National Research Council, Washington, D.C., 1990.

Saito, M. and R. Patel. Evaluating the efficacy of a microwave traffic sensor in New York City's freeway and street network. Proceedings of the Transportation Congress of ASCE, October 1995, pp. 1952–1963.

Saito, Mitsuru and Thomas G. Jin. Evaluating the accuracy level of truck traffic data on state highways. Prepared for Utah Department of Transportation research division, UDOT-09.02, February 2009.

Skszek, Sherry L. "State-of-the-Art" Report on Non-Traditional Traffic Counting Methods. FHWA-AZ-01-503, October 2001.

Taylor, Brian and Art Bergan. The use of dual weights elements (double thresh hold) to improve accuracy on weigh in motion systems, and the effect of accuracy on weigh station sorting. www.irdinc.com/library/pdf/double_threshold.pdf, 1993.

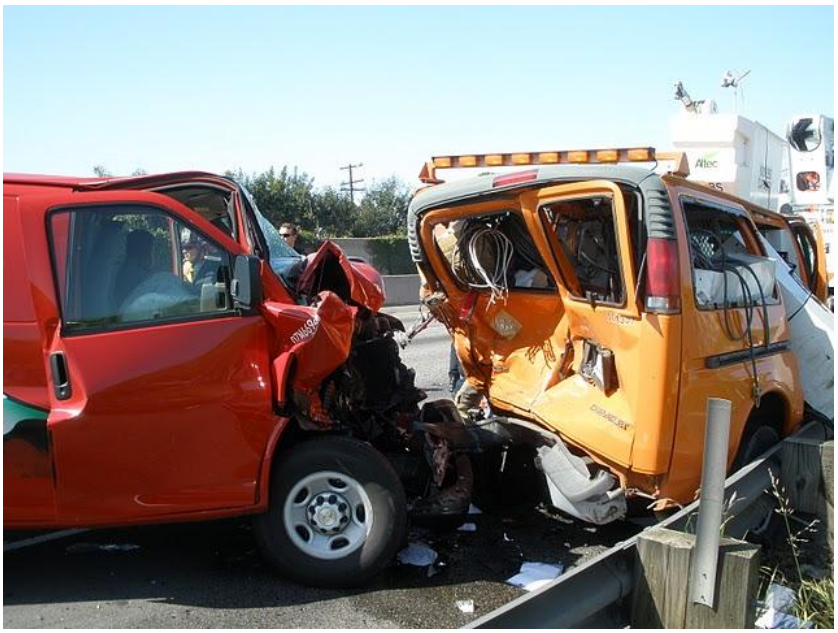
United States Department of Transportation, Federal Highway Administration. Field Test of Monitoring of Urban Vehicle Operations Using Non-intrusive Technologies. FHWA-PL-97-018, May 1997.

Victoria, I. C. and Walton, M. Freight data needs at the metropolitan level and the sustainability of intelligent transportation systems in supplying MPOs with the needed freight data. December 2004.

Wei, C., et al. Vehicle Classification Using Advanced Technologies. Transportation research record 1551, November 1996, pp. 45–50.

1. ACCIDENT PICTURES

Pictures of the accident that occurred on March 10, 2010. Two Caltrans employees were seriously injured.



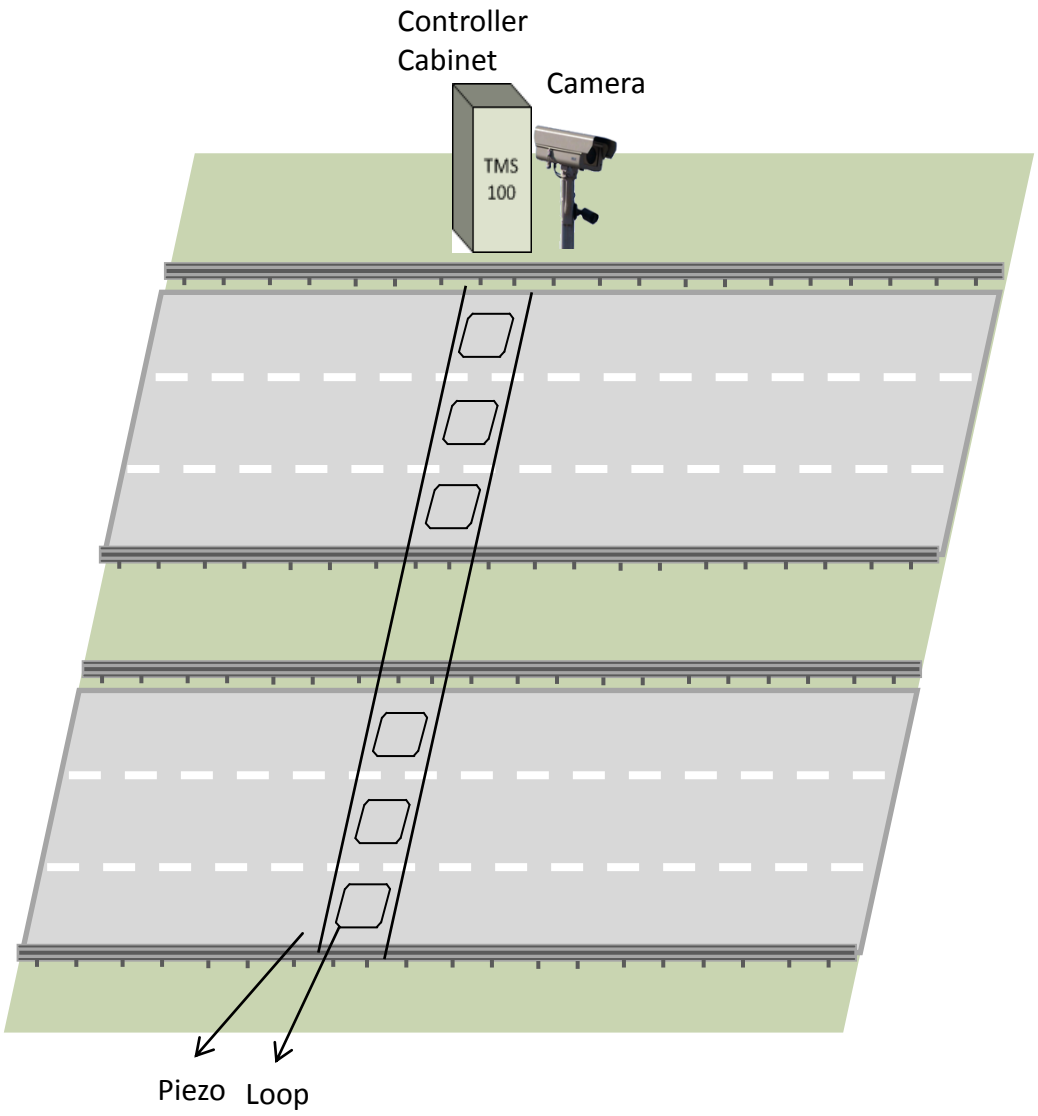
Caltrans

600 LBS CAPACITY
LBFD
LBFD

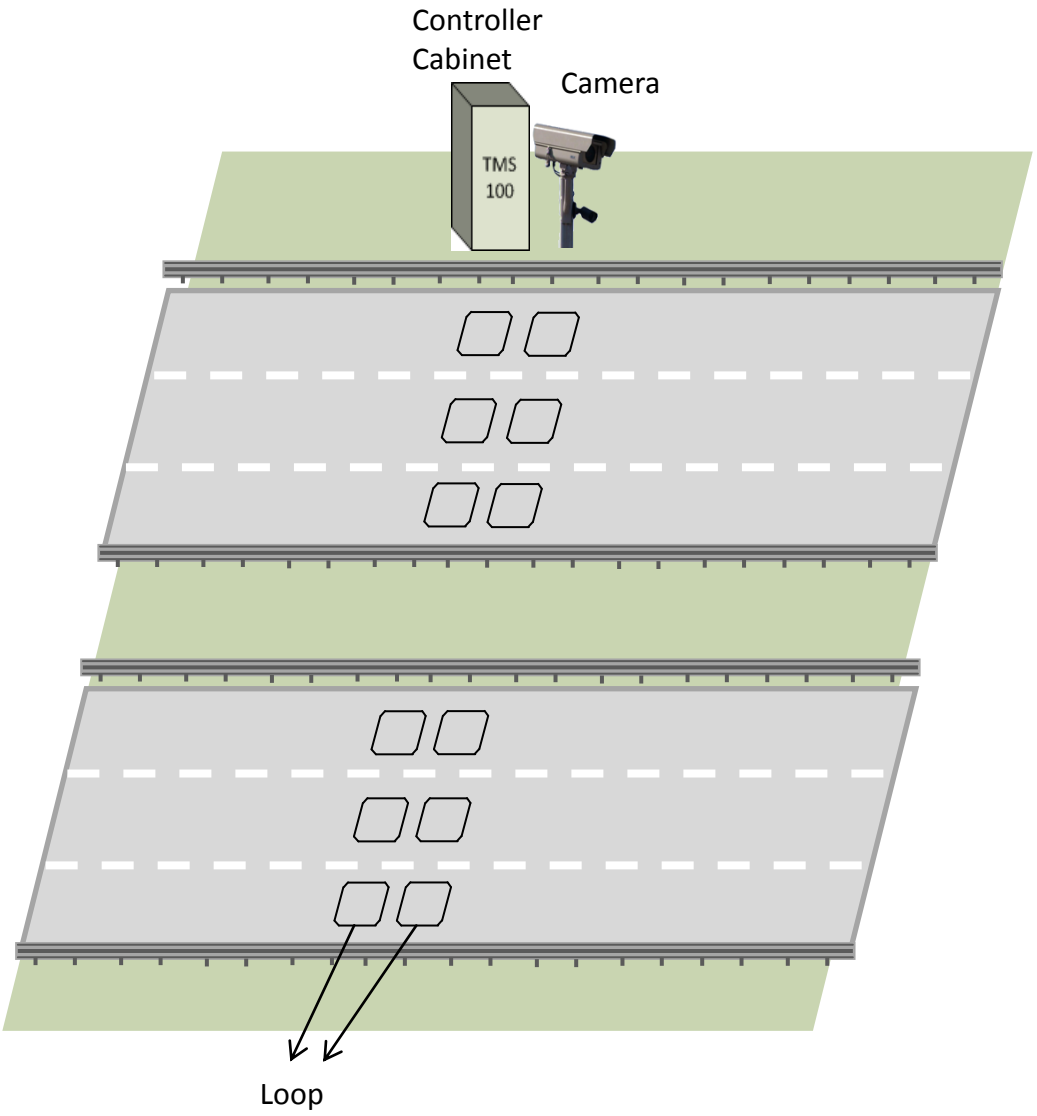
2. LOCATIONS OF INSTALLED TMS 100 UNITS

Station	County	Route	Post Mile	Description	Cabinet Location
464	LA	60	0.281	Westbound at Boyle Ave.	WB on from Soto St.
464	LA	60	0.281	Eastbound at Boyle Ave.	EB on from Soto St.
98	LA	60	R 2.22	Eastbound east of Indiana St.	EB on from Indiana St.
98	LA	60	R 2.22	Westbound east of Indiana St.	WB on from 3rd St.
99	LA	60	R 3.88	East of JCT. RTE. 710	WB shoulder at Belvedere Park POC
499	LA	60	R 8.2	East of Paramount Blvd.	EB shoulder
100	LA	60	R 10.6	West of Peck Rd.	WB shoulder
607	LA	60	R 25.464	West of JCT. RTE. 57 North	WB shoulder
120	LA	60	R 26.57	Westbound east of JCT. RTE. 57 North	WB on from Phillips Ranch Rd.
120	LA	60	R 26.57	Eastbound east of JCT. RTE. 57 North	EB on from Diamond Bar Blvd.
671	LA	60	R 29.8	Eastbound east of JCT. RTE. 71	EB on from RTE. 71/Rio Rancho Rd.
671	LA	60	R 29.8	Westbound east of JCT. RTE. 71	WB on from Reservoir St.
37	LA	710	7.6	North of Pacific Coast HWY (JCT. RTE. 1)	NB shoulder
40	LA	710	19.1	Northbound North of Firestone Blvd.	NB on from EB Firestone Blvd.
40	LA	710	19.1	Southbound North of Firestone Blvd.	SB on from EB Firestone Blvd.
41	LA	710	23.28	South of JCT. RTE. 5	NB shoulder
435	LA	710	23.75	South of JCT. RTE. 60	SB shoulder
436	LA	710	27.11	North of JCT. RTE. 10	SB shoulder
220	LA	605	2.31	North of Carson St.	NB shoulder
222	LA	605	11.0	North of Telegraph Rd.	NB shoulder

3. SCHEMATIC OF DATA COLLECTION SET UP



Automated Vehicle Classification Station



Vehicle Count Station

4. TMS 100 HANDBOOK

The attached *TMS 100 User Guide* provides information on setting up the units and modifying the parameters.

TMS 100 (Wizard 1) User Guide

Copyright © 2010 CASE Global Technologies, Inc. All rights reserved.

3/28/2010

http://www.casesystemsinc.com/
Tel: 949-268-1865
18 Morgan Ste. 200 A, Irvine, CA 92618

Table of Contents

TABLE OF CONTENTS 2
TMS 100 MODES 6
CONFIGURATION AND STATUS 10
TMS 11
CONFIGURATION AND STATUS 13
LOOP STRING CONFIGURATION 14
TMS TELNET SESSION 17
SINGLE LOOP CONFIGURATION CABLE MAPPING 20
DETECTOR OUTPUT DIAGRAM 21

INDEX 24

The TMS 100 (Wizard 1) is a wireless GSM modem with 32 channel digital inputs, 1 RS 232 port, 8 digital outputs, and is java programmable. The TMS 100 also operates as an external wireless modem with serial connectivity. The TMS 100 is an ideal solution for telemetry, SCADA, and remote sensory devices. The TMS 100 supports two different applications, the **TMS Modem** and **TMS**.

Figure 1- TMS 100 Modem

The **TMS Modem** is a wireless modem. It functions like a dialup modem except it transmits data over the GSM wireless network (AT&T in the US) instead of phone lines.

The TMS is used by departments of transportation to monitor traffic along highways and main roads. TMS is an intelligent loop detection software that polls the output of any inductive loop detector card and provides volume, speed, loop occupancy and length classification.

Front Panel

The following picture shows the front panel of the TMS 100.

Figure 2 – TMS 100 Modem Front: Shows both RS-232 Port and Status LEDs.

The TMS 100's front panel is consisting of:

- Status LED's
- Reset Button
- Select Button
- RS-232 Port

1. RS-232 Serial port

The TMS 100 Modem supports the following DB 9 pins

PIN (DB9)	Description
1	DCD – Data Carrier Detect
2	RX – Receive Data
3	TX – Transmit Data
4	Not Used
5	Ground
6	Not Used
7	RTS – Request To Send
8	CTS – Clear To Send
9	Not Used

Serial Port Baud rates *The TMS 100 supports the following baud rate 1200, 2400, 4800, 9600, 19200, 28800, 38400, 57600, and 115200.*

2. Status LED's

The TMS 100 is equipped with Six LEDs on the front panel as described in the table below:

LED	Description	LED	Description
Power	On when powered up	RSSI	Off – very week signal Blinking – adequate signal Solid – very strong signal
Mode 0	See TMS 100 Modes Appendix A	Tx/Rx	Blinks as data is transferred to serial port
Mode 1		GSMR	On when is register on GSM network

3. Reset Button

To reset the TMS 100, insert a straightened paperclip into the Reset hole to press the button. Keep pressing and power cycle (off and on) the device. Wait for at least 5 seconds to release the button. Then wait for the device to finish booting.

4. Select Button

TMS 100 should be preconfigured to startup in the correct mode depending on the application. In case, the user needs to change the TMS 100's mode read on: The TMS 100 can be configured to run in 4 different modes. The mode is selected either by pressing the *select* button in the front of the modem or by setting the default mode using a jumper on the circuit board inside the TMS 100. Also, the select button left of the status LED's allows the user to toggle between modes. A paper clip or other pointy object is required.

TMS 100 Modes

TMS Mode

Mode 0 (OFF) Mode 1 (OFF)

- Required by TMS.
- The RS – 232 Port is not active.

Figure 3 - TMS Mode

TMS 100 Modem Mode

Mode 0 (ON) Mode 1 (OFF)

- Java serial port mode
- Used when running TMS 100 Modem application

Figure 4 - RS 232/TMS 100 Modem

Configuration Mode

Mode 0 (OFF) Mode 1 (ON)

This mode is used for storing the factory setting of the modem. This is done before shipping the modem from Case Global Technology. Factory settings include:

- Loading Java firmware (firmware can also be loading remotely over TCP/IP)
- Configuring APN's.

Figure 5 - Configuration Mode for Loading Java

AT Mode

Mode 0 (ON) Mode 1 (ON)

- Sets up modem for AT modem.
- This is used for dialup PPP connections. A PPP modem driver must be installed on PC.

Figure 6 - AT Mode

Rear Panel and Connectors

The following figure illustrates the rear panel of the TMS 100.

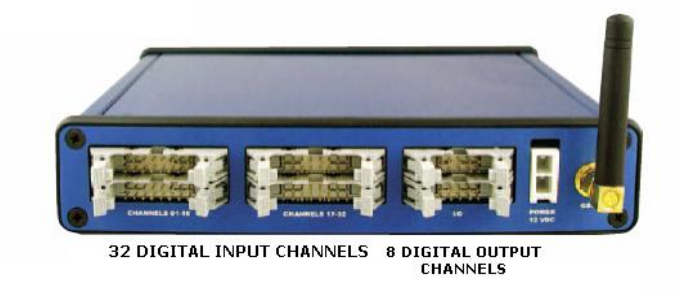


Figure 7 – TMS 100 (Wizard 1) Modem Back

1. 32 digital input channels

There are 4 sets of 8 channel connectors that make up 32 channel inputs. A cable with 16 pin ribbon connectors connects to one of the four TMS connectors shown above.

- For a single loop configuration, one cable would support up to 8 lanes. See TMS Cable Mapping[1].
- For dual loop configuration; a dual loop with 4 lanes would take up to 8 channels and use only one cable. Any more lanes would require an extra cable. See TMS Cable Mapping[1]

The cable U shaped connector connects to a detector rack where the output of the detector card is monitored. Each cable wire is labeled with a number[2]. This cable is supplied by Case Global Technology.

[1] Appendix A
[2] A ground wire is also supplied which must be properly grounded for the detector output to be properly sensed

2. 8 Digital Output Channels

Similar to the 32 input channels above, the 10-pin ribbon connector is connected to the TMS 100 that carries digital 8 different java programmable digital output channels.

3. GSM Antenna

There are various options as to the GSM antenna depending on the signal strength. In areas with powerful signal RSSI=60, a small antenna is adequate and can function will inside a traffic cabinet. In areas with weaker signal, RSSI = 80, an antenna is external is mounted. If the signal is really weak RSSI=95+ a high gain antenna is required. Case Global Technology resells compatible antennas.

4. DC 12V: Power Connector

The TMS 100 modem can either, receive TCP/IP connections from a host computer or it can connect to a host computer to provide wireless connectivity for dialup only applications.

TMS 100 Modem receiving TCP/IP connections from a host computer application

TCP/IP enabled application running on a host computer can connect to the TMS 100 Modem cabled to the serial device. The serial device could be a utility meter, a traffic counter, changeable message sign, an irrigation system, or any other device with an RS 232 serial port. The application using TMS 100's IP address and port can connect either over the internet or a custom APN[3]. Once a connection is established, data can be transferred between the application and the serial device via the TMS 100 Modem.

[3] For information on Custom APN's, go to att.com or perform a Google search.

Configuration and Status

By typing the DNS Cingular hostname "<phone number>.internet.mycingular.com" of the hostname in the web browser, a user can see the current status of the TMS 100 Modem

From the Web page, the user can configure the listening port, Destination IP and baud rate of the modem. Once the listening port and baud rate are set, the "Modify Settings" button is pressed. The new settings are stored and the modem is rebooted before the new settings take effect. This process takes about 30 seconds. Any data written into the serial port of the TMS 100, would be forwarded to the destination IP through UDP[4] this IP address uses the same port number as the listening port.

TMS

TMS is used by the transportation industry to monitor vehicle traffic on major roads and highways. In a dual loop configuration, TMS will measure traffic volume, average speed, standard deviation speed, lane occupancy, and vehicle length bins of 0-20 feet, 20-40 feet, 40-60 feet, and 60+ feet. Bins are created for either 15 minute or 1 hour time intervals. In a single loop configuration, The TMS measures volume and lane occupancy only.

The TMS application must be properly connected using a special cable to the output of 222 type detector cards. The Data collector in the traffic center will automatically poll the TMS 100 to download the traffic data to a database (i.e. Oracle, MS SQL, or MS Access)

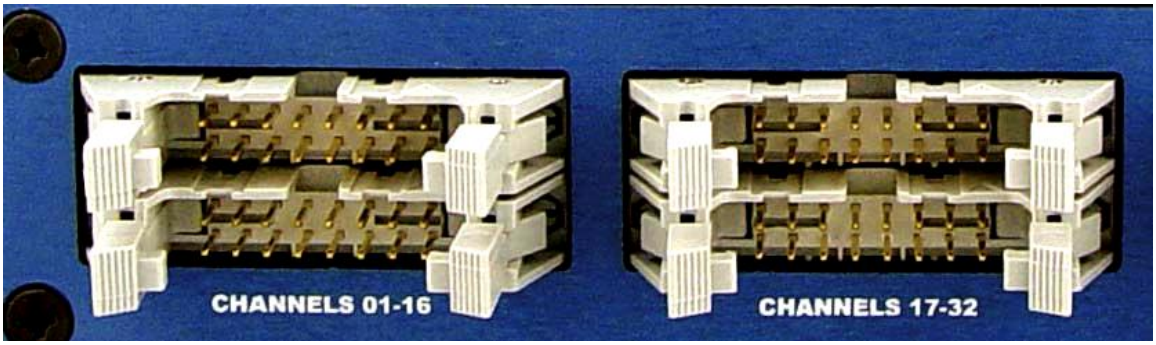


Figure 8 - 32 digital input channels

Important: The cable mapping is how lanes in the roadway are store collected and stored into the database. Different agencies follow their one lane naming conventions. Some may want to assign lane 1 to the fast lane on the freeway. Others may want lane 1 to be the closest lane to the traffic cabinet.

Each TMS cable must be grounded. It is OK to have unconnected TMS cable wires. For example if there is a 3 lane dual loop configuration, wires 7 and 8 will not be connected?

For more on how The TMS cable is connected to the output of the speed detector refer to

Configuration and Status

By typing the IP address of the hostname in the web browser, a user can see the current status of the TMS application. See browser page below:

To Modify Settings, the user can configure the number of lanes, dual or single loop, trap distance in feet (only applies to dual loop), and listening port (for telnet and data collector downloads), and UDP broadcast interval. Once the connection port and baud rate are set, the "Modify Settings" button is pressed. The new settings are stored and the TMS 100 will reboot before the new settings take effect. This process takes about 30 seconds.

Modifying Setting

- Listening port –TCP/IP listening port used by the telnet application that logs into TMS.
- Trap distance – is set to the number of feet separating the speed trap (center of leading loop and center of trailing loop). Values can range from 10 to 20 feet.
- Reporting mode – allows the user to select between 15 minutes and 1 hour reporting bins. The user can also specify the various UDP broadcasting intervals. UDP is off by default.
- The number of lanes can range between 1 and 14 lanes.

LOOP STRING CONFIGURATION

Single Loop

The single loop algorithm estimates the speed and length of vehicles traveling over a single loop. The single loop speed algorithm uses an estimation formula which requires the user to provide the average length of a vehicle traveling in the lane. Since traffic in the inner lanes composes almost entirely of cars and small trucks, vehicle lengths are much easier to predict. For this reason, the single loop requires the user to provide the average length of the vehicle in the inner lane. Once the speed is calculated in the inner lane, the user can scale the speed to the outer lanes by applying a speed factor. Typically, traffic speeds are 5 percent slower from the inner lane to the outer lanes. The user can factor this speed difference on a per site basis.

Example

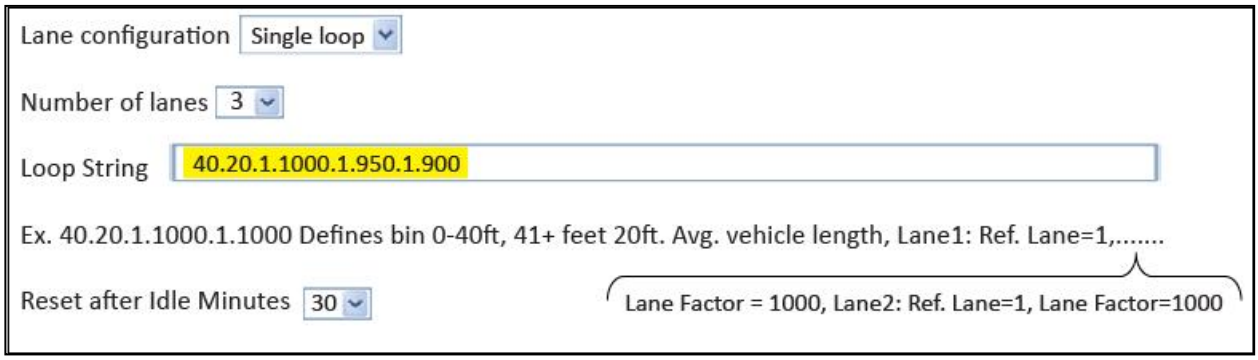
Let's imagine a 3 Lane freeway, we know that the average speed in the fast lane is around 75mph, and since there are generally only a few small trucks in the fast lane the average length of the vehicles in this lane is 20ft. Using this lane as a reference we assume that the speed factor is 1000. Note that the Speed factors are in 10^{th} of a percent, so 951 is 95.1% Keeping that in mind we can calculate the average speed in the second lane. If the speed is approximately 5% lower in the second lane the speed factor can be calculated as:

$$1000 – (1000 \times 0.05) = 950$$

Following the same logic the speed factor

In the 3^{rd} lane would be:

$$1000 – (1000 \times 0.1) = 900$$



Setting the best time Interval

Speed is calculated in short time intervals; say every 30 seconds, 1 minute, or 2 minutes. The current speed of traffic calculated is based on the speed calculated from the previous time interval. For example, if the user wants TMS to calculate speeds every 1 minute, vehicle speed and vehicle lengths at 12:31:20 are based on the speed of traffic from 12:30 to 12:31. If average traffic speed is more constant then the user may decide to use a 2 minute time interval. If traffic speed is more dynamic the user may decide to use a 30 second time interval to calculate speed. Being able to use a 2 minute time interval is more desirable since the average speed calculated is derived from a larger sample size. However, if traffic speed fluctuates more, then a shorter time interval would be preferred.

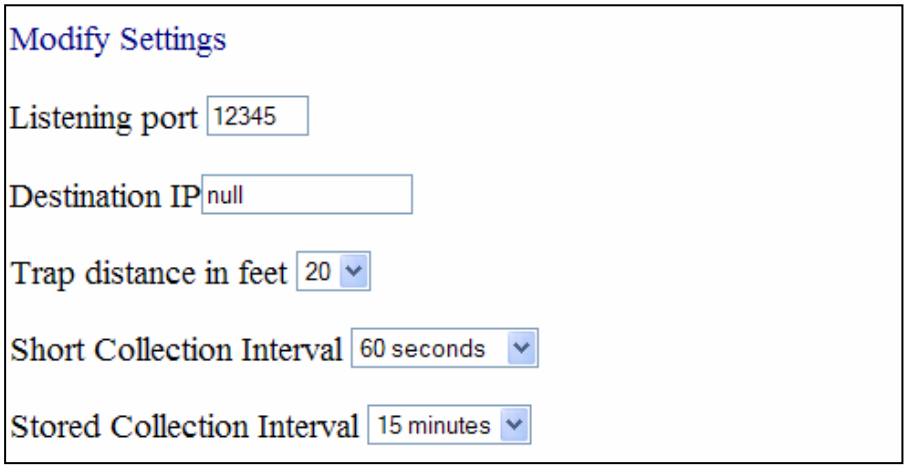


Figure 9 - Modify Settings

Dual Loop

In dual loop configuration, TMS™ polls both the lead and trail loops in real-time and provides accurate volume, speed, occupancy, and vehicle length counts. The dual loop does not require the user to provide reference lane or speed factor in writing the loop string; however the user needs to define the length bin thresholds. Reporting intervals are also user definable.

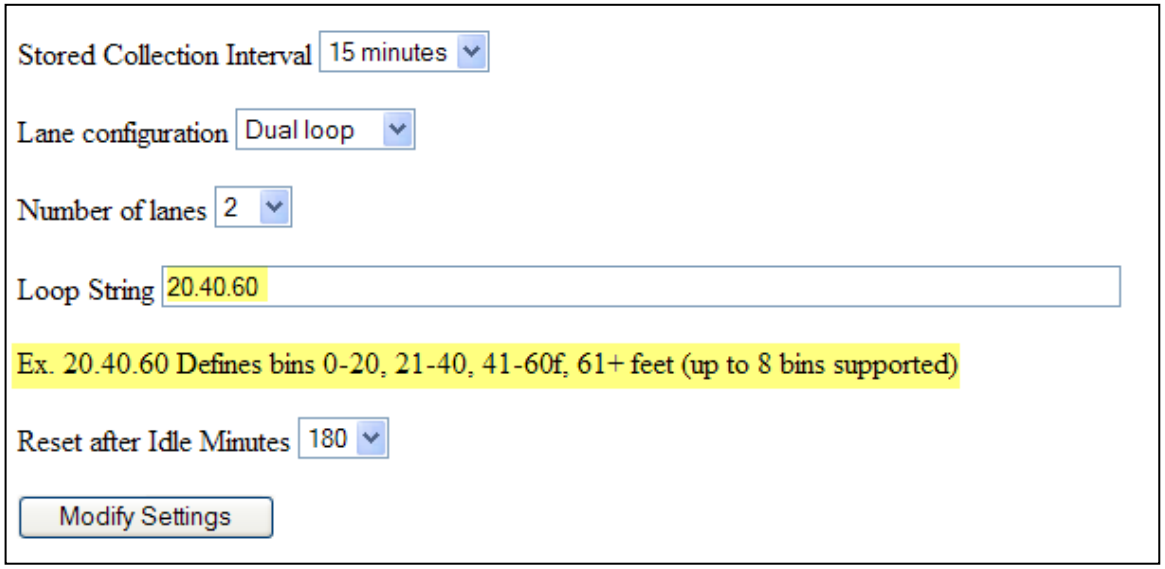


Figure 10 - Dual Loop

In this example:

- The Stored Collection Interval is set to 15 minutes “15 minute bins”. Data can also be stored in 5, 30, and 60 minute intervals.
- The loop string defines 4 bins based on the 20, 40, and 60 foot thresholds.
- TMS will reset after 3 hours if there is no attempt to communicate with it. Note that the data collector contacts the TMS 100 on a regular basis so the modem can go several days without a reset.

TMS Telnet Session

A telnet session is established to look at live traffic. Useful diagnostic commands include h, 1-9, l, and v. Hyper-terminal can be used to establish a telnet session. See "Connect To" dialog below as an example of how to connect to a host address/port combination using TCP/IP.

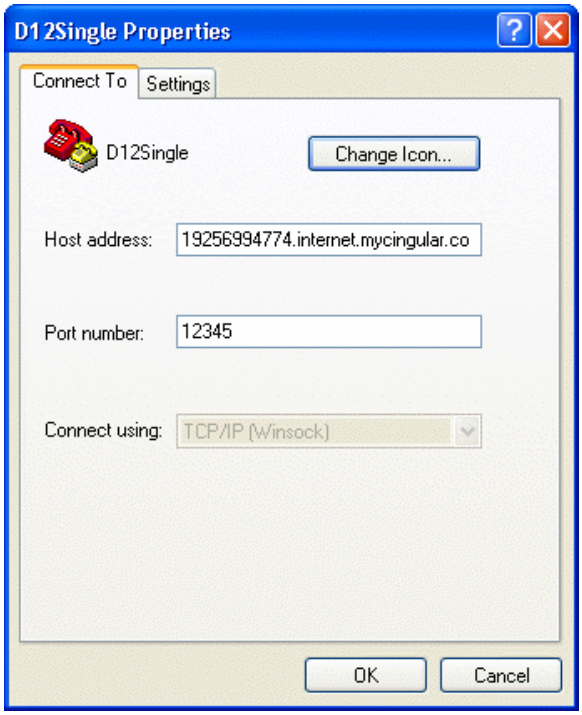


Figure 11 - Hyper-terminal configuration

- Once logged in using telnet, the user will see the ">" prompt. The user can type "h" for help. Below are some useful commands and how they work. Other telnet programs such as Tera Term or Putty can be used too.
- Once done using telnet, the user must log out using the "x" command. If not, the user will likely have trouble reconnecting for the next few minutes.
- If no commands are typed, the telnet session will log the user off[5] after approximately 2 minutes. This is to prevent wasting system resources. The user can easily re-log in if disconnected.
- Hyper-terminal icons can be saved in a folder. The user only needs to double-click on the icon to log in.

[5] The user can type "h" command to prolong the session.

Diagnostic Commands

- "v" – command toggles on and off the vehicle report. The vehicle report[6] which includes the speed, vehicle length, and timestamp of traffic in all lanes.
- "1" – "9" shows both the loop and vehicle reports one lane at a time. This diagnostic is not available for lanes 10 – 14. The v command will still show these lanes.
- "l *(Letter L)*" – Toggles on and off the loop report[7].

The "v" Command Example

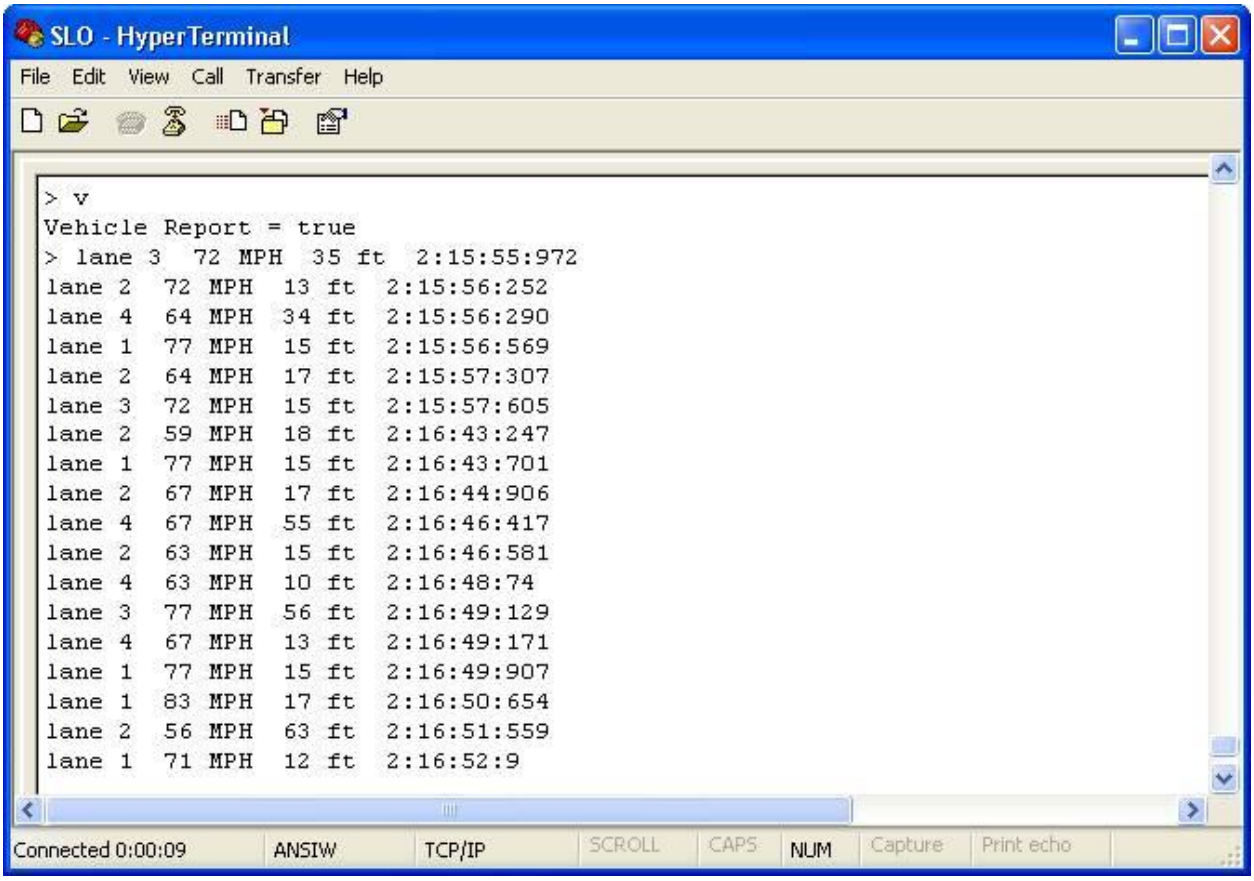

SLO - HyperTerminal
File Edit View Call Transfer Help
> v
Vehicle Report = true
> lane 3 72 MPH 35 ft 2:15:55:972
lane 2 72 MPH 13 ft 2:15:56:252
lane 4 64 MPH 34 ft 2:15:56:290
lane 1 77 MPH 15 ft 2:15:56:569
lane 2 64 MPH 17 ft 2:15:57:307
lane 3 72 MPH 15 ft 2:15:57:605
lane 2 59 MPH 18 ft 2:16:43:247
lane 1 77 MPH 15 ft 2:16:43:701
lane 2 67 MPH 17 ft 2:16:44:906
lane 4 67 MPH 55 ft 2:16:46:417
lane 2 63 MPH 15 ft 2:16:46:581
lane 4 63 MPH 10 ft 2:16:48:74
lane 3 77 MPH 56 ft 2:16:49:129
lane 4 67 MPH 13 ft 2:16:49:171
lane 1 77 MPH 15 ft 2:16:49:907
lane 1 83 MPH 17 ft 2:16:50:654
lane 2 56 MPH 63 ft 2:16:51:559
lane 1 71 MPH 12 ft 2:16:52:9
Connected 0:00:09
ANSIW
TCP/IP
SCROLL
CAPS
NUM
Capture
Print echo

Figure 12 - "v" command example

[6] For single loop systems the length and speed are not available.
[7] The loop reports displays loops as vehicles pass over them. This is useful in diagnosing incorrect wiring or faulty loops.

The Single lane command

In this example, lane 4 is used to provide further analysis.

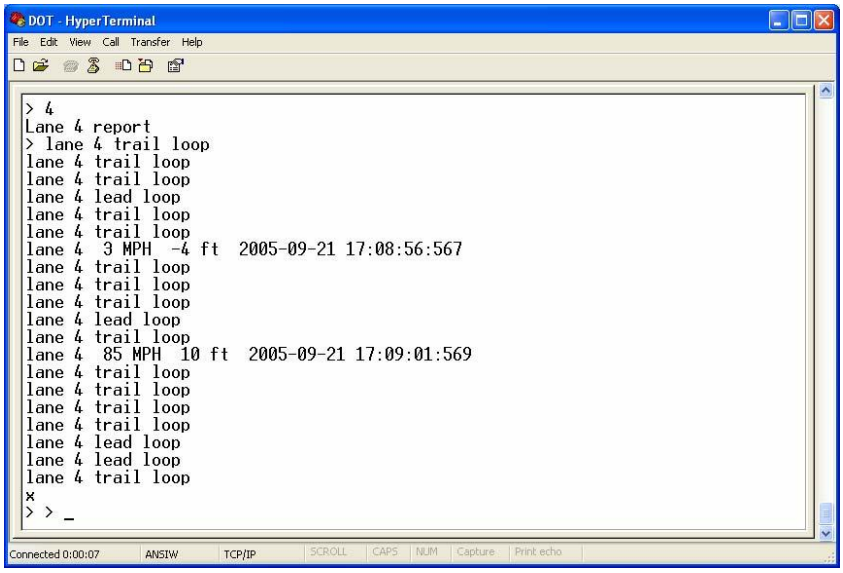

DOT - HyperTerminal
File Edit View Call Transfer Help
> 4
Lane 4 report
> lane 4 trail loop
lane 4 trail loop
lane 4 trail loop
lane 4 lead loop
lane 4 trail loop
lane 4 trail loop
lane 4 3 MPH -4 ft 2005-09-21 17:08:56:567
lane 4 trail loop
lane 4 trail loop
lane 4 trail loop
lane 4 lead loop
lane 4 trail loop
lane 4 85 MPH 10 ft 2005-09-21 17:09:01:569
lane 4 trail loop
lane 4 trail loop
lane 4 trail loop
lane 4 trail loop
lane 4 lead loop
lane 4 lead loop
lane 4 trail loop
> > _
Connected 0:00:07 ANSIW TCP/IP

Figure 13 - Lane 4 report showing extra trail loop reports causing incorrect speed and length calculations

The user types “4” at the “>” prompt. The user should see lead and trail loop combinations like lane 1 in the figure below. Instead, the user is seeing too many tailing loops for lane 4 in the figure above. This information is used in remotely diagnosing detection problems.

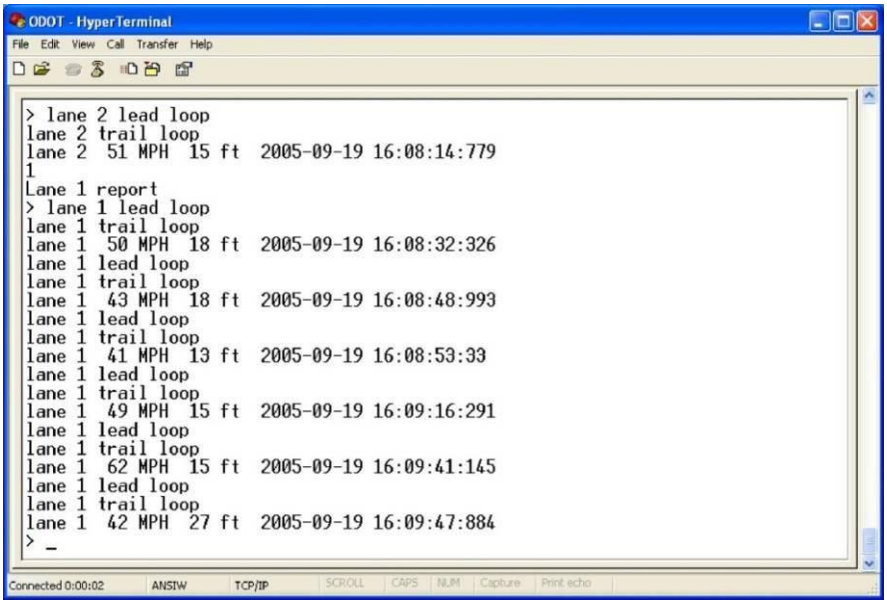

ODOT - HyperTerminal
File Edit View Call Transfer Help
> lane 2 lead loop
lane 2 trail loop
lane 2 51 MPH 15 ft 2005-09-19 16:08:14:779
1
Lane 1 report
> lane 1 lead loop
lane 1 trail loop
lane 1 50 MPH 18 ft 2005-09-19 16:08:32:326
lane 1 lead loop
lane 1 trail loop
lane 1 43 MPH 18 ft 2005-09-19 16:08:48:993
lane 1 lead loop
lane 1 trail loop
lane 1 41 MPH 13 ft 2005-09-19 16:08:53:33
lane 1 lead loop
lane 1 trail loop
lane 1 49 MPH 15 ft 2005-09-19 16:09:16:291
lane 1 lead loop
lane 1 trail loop
lane 1 62 MPH 15 ft 2005-09-19 16:09:41:145
lane 1 lead loop
lane 1 trail loop
lane 1 42 MPH 27 ft 2005-09-19 16:09:47:884
> _
Connected 0:00:02 ANSIW TCP/IP

Figure 14 - Lane 1 report shows lead and trail events plus the resulting length and speed calculations

Single Loop Configuration Cable Mapping

Cable	TMS 100 Wire	Detector Loop Output
Chan1-8	Ground	Grounded to detector
Chan1-8	1	Lane 1
Chan1-8	2	Lane 2
Chan1-8	3	Lane 3
Chan1-8	4	Lane 4
Chan1-8	5	Lane 5
Chan1-8	6	Lane 6
Chan1-8	7	Lane 7
Chan1-8	8	Lane 8
Chan9-16	Ground	Grounded to detector
Chan9-16	1	Lane 9
Chan9-16	2	Lane 10
Chan9-16	3	Lane 11
Chan9-16	4	Lane 12
Chan9-16	5	Lane 13
Chan9-16	6	Lane 14

Figure 15 - SINGLE LOOP CONFIGURATION

Detector Output Diagram

The following diagram shows the back of the detector rack labeling its wiring connections. The diagram shows an input file with 2 channel detector card; in the dual loop configuration the "lead" loop is the first detector output of the detector card and the second detector output is the "trail" loop of the detector. In a single loop configuration, the first output is lane 1 and the second out put is lane 2, lane 3 and lane 4, lane 5 and 6, etc…

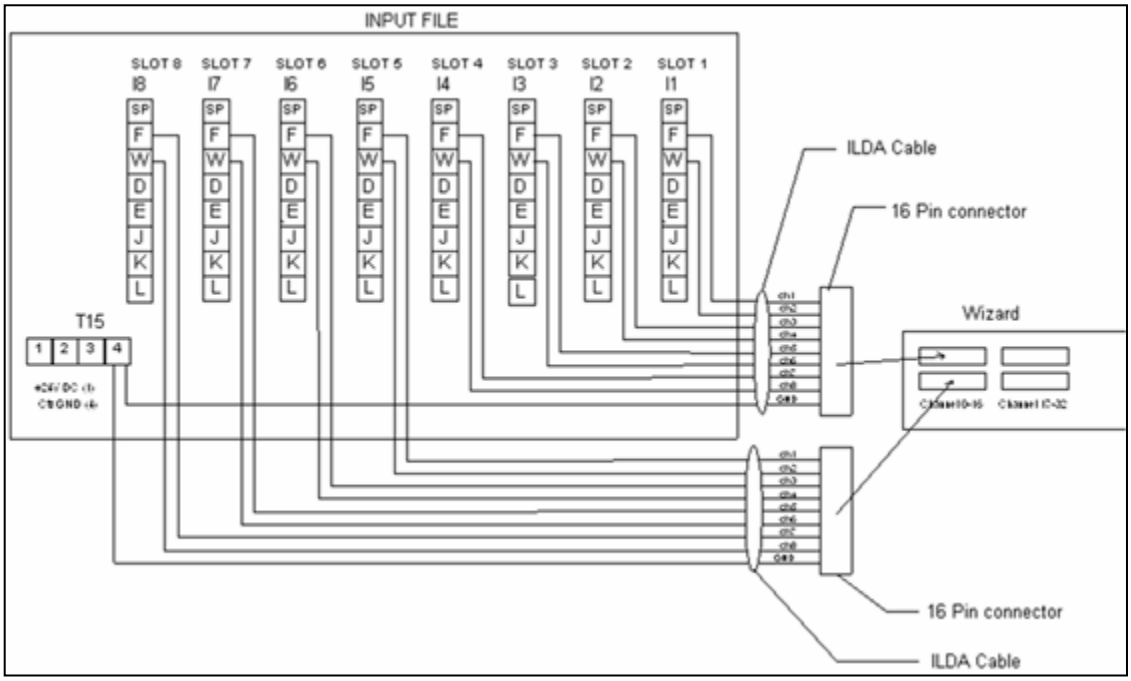


Figure 16 – Detector output diagram

FAQ

This section shows some of the frequently asked questions.

How can we minimize the amount of data usage to keep our monthly wireless bills lower?

Here are some pointers that will minimize the data usage.

1. Make sure that UDP broadcast is not on. This can be done by going to the TMS web page of each TMS 100 to make sure that no destination IP is specified. This will make a big difference.

2. In the task manager you can adjust the polling to every 45 minutes instead of every 15 minutes. This should help some.

3. Also, once this is done. Check the bill to see what your usage is after a month. You may find that the usage is lower.

(Basic Networking)

ASCII
(American National Standard Code for Information Interchange)

AT Command Set
Commands issued by intelligent device to a modem to perform functions, such as to initiate call, to answer call, or to transmit data.

Bandwidth
The amount of transmission capacity that is available on a network at any point in time.

EDGE
Enhanced Data rates for GSM Evolution -- this 3G technology allows wireless transmission of data at speeds up to 384K bit/sec. It's based on GSM technology and allows for high-bandwidth services such as multimedia. It has more support in North America than in other areas where technologies such as CDMA2000 and UMTS may be favored.

Ethernet
International standard networking technology for wired implementations.

GPRS
Standard for packet communications utilizing Global Standard for Mobility (GSM) infrastructure

GPS
Global Positioning System

GSM (Global System for Mobile Communications)
Standard for digital communications

HyperTerminal
HyperTerminal is a communications program bundled with multiple versions of the Microsoft Windows[8] operating system. It is a tool used when connecting to other computers, bulletin board systems (BBSs), and a host of other Internet-related services.

[8] Windows Vista does not include HyperTerminal.

LAN (Local Area Network)
A collection of devices connected to enable communications between themselves on a single physical medium.

Modem (Modulator-Demodulator)
Modem is a device that converts digital signals into analog signals and vice versa. Used for conversion of signals for transmission over telephone lines.

Network
A number of devices connected to enable the device to communicate with any other device over a physical medium.

Packet
A collection of data transmitted over a digital network in a burst.

SIM
Subscriber Identity Module

Telnet
Telnet is a TCP/IP application that enables a user to log in to a remote device.

TCP/IP
(Transmission Control Protocol/Internet Protocol)

VPN
A type of technology designed to increase the security of information transferred over the Internet. VPN can work with either wired or wireless networks, as well as with dial-up connections over POTS. VPN creates a private encrypted tunnel from the end user's computer, through the local wireless network, through the Internet, all the way to the corporate servers and database.

WAN
A communication system of connecting PCs and other computing devices across a large local, regional, national or international geographic area.

A

AT modem, 7

B

bins, 12, 14

D

Database, 33

H

hostname, 11, 14
HyperTerminal, 37

I

TMS, 3, 6, 8, 12, 14, 16, 17, 18, 19, 22, 23, 26, 28, 29, 30, 33, 34
inputs, 3, 8
IP address, 10, 11, 14, 26

L

loop detection, 3, 27
LOOP STRING, 15

M

Modes, 5

O

occupancy, 3, 12, 17, 27
Output, 9, 34, 35, 36

R

RS-232 Port, 4

S

speed factor, 15, 17

T

telnet, 19

U

UDP broadcast, 14

V

volume, 3

W

TMS, 3, 4, 5, 6, 8, 9, 10, 11, 12, 14, 22, 23, 31, 35
TMS 100 Modem, 3, 6